NOAA FISHERIES

Alaska Fisheries Science Center

2021 SCIENCE HIGHLIGHTS

A Look Back at What We Learned.

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Alaska Fisheries Science Center 2021 Science Highlights

A Look Back at What We Learned.

A Look Back at What We Learned

The Alaska Fisheries Science Center is composed of six divisions overseen by the Science Director's Office, which lead and carry out mission-essential research, operations, and administrative activities. We study marine life and marine ecosystems from the seafloor to the ocean surface. We also collect a variety of information on Alaska human communities that look to the ocean for their food, livelihoods, recreation, cultural enrichment, and spiritual well being.

We conducted **22** research surveys and placed **355** observers on commercial fishing vessels and in **12** processing plants.

We collected valuable biological, oceanographic, and socio-economic information and monitored fisheries catch and bycatch.

Data collected and analyzed on research and fishing vessels and in Alaska Fisheries Science Center laboratories provided the basis for updating **43** fish and crab stock assessments in 2021.

We also reviewed **19** marine mammal stock assessments, updating **5** stock assessments and **4** strategic stock assessments.

Specifically, our job is to monitor the abundance and trends (whether populations are increasing or declining) of federally managed harvestable seafood caught by commercial, recreational, and subsistence fisheries. To help predict future population abundance and trends, we study young fish and crabs as they develop and survive from eggs to adults. We also collect and analyze a variety of information on marine food webs – who eats what and how ocean conditions, like temperature, currents, and pH, affect growth and survival of plankton, fish and crabs. We also study the places where species breed, feed and rear their young.

Having data collected and analyzed over many years provides an understanding of species relationships and how Alaska ecosystems functioned in the past. This is especially important as we experience novel climate conditions due to climate change and extreme events, such as marine heatwaves.

We also study Alaska's marine mammals. We gather information for the protection and recovery of whales, porpoises, seals, and sea lions that use Alaska waters as a summer feeding ground or year-round habitat. We also share our expertise with our NOAA colleagues on the West Coast to collect a variety of information to study some species that migrate and spend part of the year in waters from Washington to California.

Our science provides the basis for sustainable fisheries management, protecting and recovering marine mammal populations, and maintaining productive marine ecosystems in Alaska.

Still under the shadow of a pandemic, we adjusted our survey operations in 2021 to continue delivering the science to support resource management

decisions. This included modifying staffing plans, conducting remote training programs, and executing new safety and operational procedures and adaptive data collection efforts.

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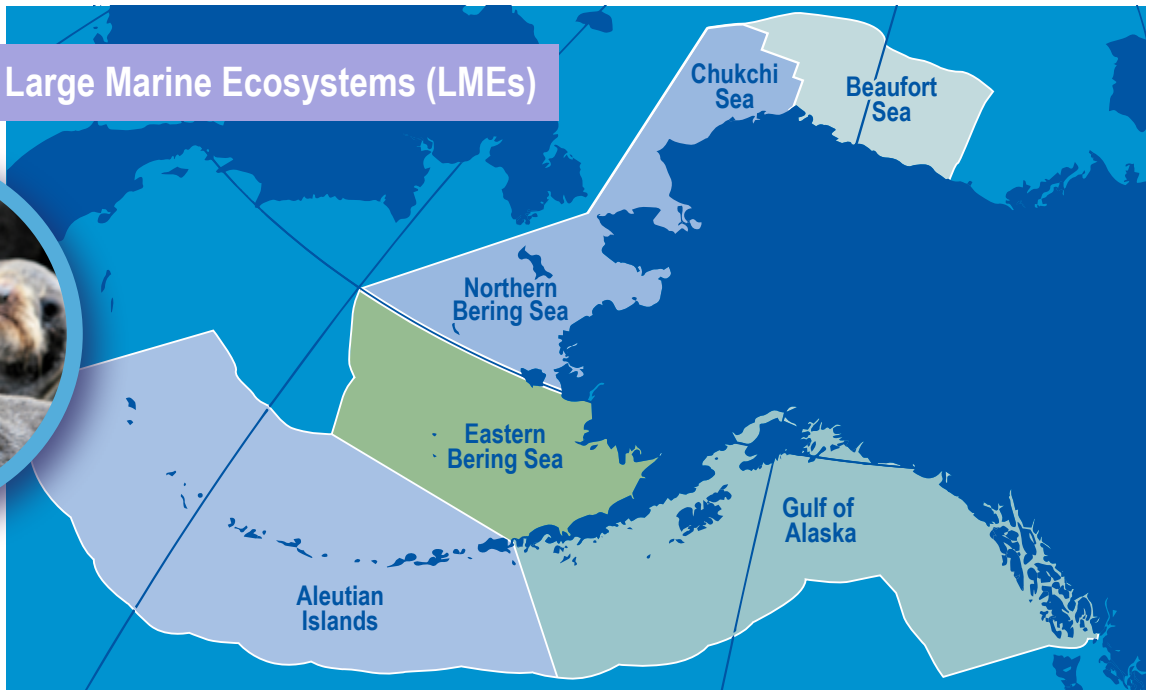
Data collected and analyzed on research and fishing vessels and in Alaska Fisheries Science Center laboratories provided the basis for updating 43 fish and crab stock assessments in 2021. We also reviewed 19 marine mammal stock assessments, updating 5 stock assessments and 4 strategic stock assessments.

For the Gulf of Alaska, Alaska Fisheries Science Center scientists completed 17 stock groundfish assessments in 2021. These included full assessments for pollock, Pacific cod, sablefish, northern and southern rock sole, shallow water flatfish, rex sole, arrowtooth flounder, Pacific ocean perch, shortraker rockfish, other rockfish, rougheye and blackspotted rockfish, demersal shelf rockfish, and Atka mackerel. Partial assessments were conducted for deepwater flatfish (dover), flathead sole, northern rockfish and dusky rockfish.

For the eastern Bering Sea and Aleutian Islands, Alaska Fisheries Science Center scientists completed 17 groundfish assessments in 2021. These included full assessments for eastern Bering Sea pollock, Aleutian Islands pollock, eastern Bering Sea Pacific cod, Aleutian Islands Pacific cod, sablefish, yellowfin sole, flathead sole, Alaska plaice, northern rockfish and Atka mackerel. Partial assessments were conducted for Greenland turbot, arrowtooth flounder, Kamchatka flounder, northern rock sole, Pacific ocean perch, blackspotted and rougheye rockfish and skates. We also conducted full or updated 5 crab stock assessments in FY21 for Eastern Bering Sea snow crab, Bristol Bay red king crab, Eastern Bering Sea Tanner crab, Norton Sound red king crab and Aleutian Islands golden king crab.

Here is a brief look at some of the key scientific activities in FY21 that informed these and our marine mammal stock assessments, and helped us understand how climate change is affecting Alaska marine ecosystems.



Age and Growth Research

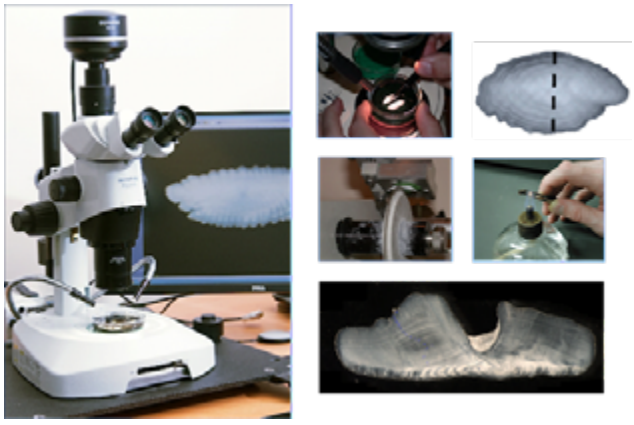
Data on fish and crab size, combined with age information, provide growth rates. We assess the age and growth rates of fish species and age groups or classes within populations to monitor, assess, and manage populations better. In 2021, on fishing and research vessels, we measured the length of nearly 1.5 million fish. Kodiak Laboratory scientists also measured 48,606 crabs.

Scientists and observers collected 67,000 otoliths (ear stones). Like tree rings, otoliths contain a record of each year of a fish's life. In our laboratories, scientists used microscopes and aging techniques to determine the age of 26,400 fish from growth information on otoliths collected in prior years.

Like otoliths, fish scales and skate vertebrae provide information about fish age and species. In 2021, observers collected 7,030 salmon scales and 35 skate vertebrae.

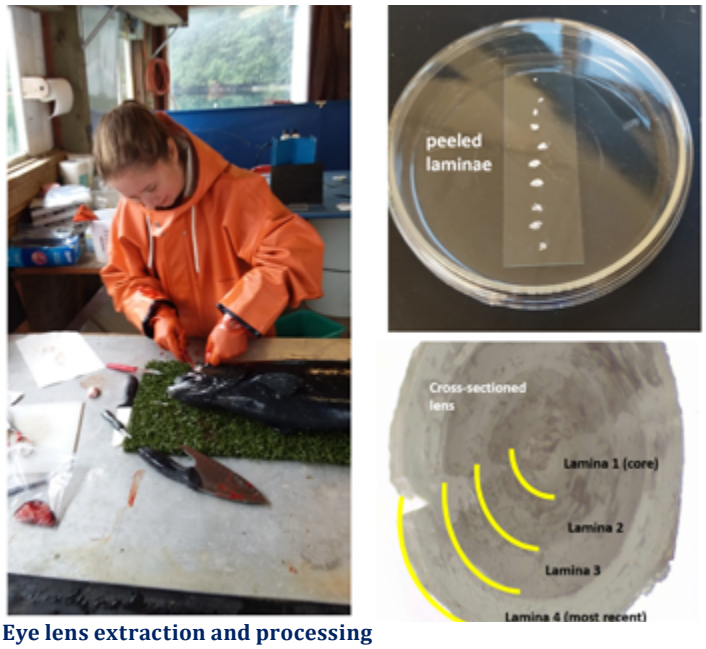
In 2021, we made headway in using new technologies to help us age fish faster.

OLD METHOD



NEW METHOD

Using Fourier Transform Near-Infrared Spectroscopy increases efficiency 600 - 800 percent over traditional manual method for examining otoliths to determine fish age.



Eye lens extraction and processing

- We continued using mobile technology and were able to determine the age of 1,700 fish while survey vessels were still at sea.
- Observers also used other new technology to conduct maturity scans of 6,337 fish at sea.
- In the laboratory, we are using other innovative technology to help us do our jobs more efficiently. For example, Fourier Transform Near-Infrared Spectroscopy is an automated and efficient process for scanning otoliths to determine fish ages, saving valuable staff time.
- We developed a novel approach to age fish by looking at fish eyes.
  - Auke Bay Laboratories staff have developed methods using stable isotopes (e.g., oxygen, carbon, nitrogen, hydrogen and sulfur) to study lens layers in fish eyes.
  - With this approach, they can learn about physiological and dietary information preserved from birth through the full lifetime of examined fish.
  - In FY21, they tested this method on Chinook salmon, sablefish, walleye pollock, and Pacific halibut.

Predator-Prey and Food Web Relationships

Through innovation and collaboration, we are learning more about predator-prey and food web relationships. At the same time, we continue tried-and-true methods for studying fish diet in our Fish Food Habits Laboratory.

During beach seining and set camera studies in 2021, scientists from our Newport and Kodiak laboratories collected >3,000 samples to learn more about fish and crab fat content and diet.

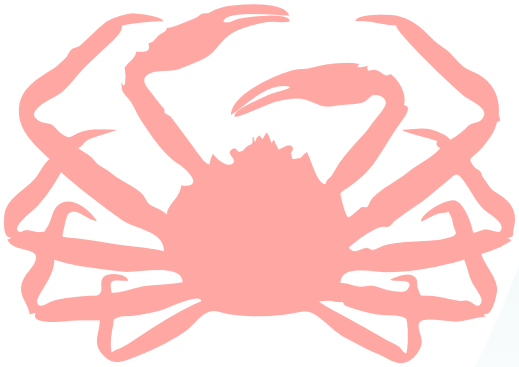
Scientists at the Auke Bay Laboratories Recruitment, Energetics, and Coastal Assessment Program and Newport's Marine Lipids Ecology Laboratory made significant improvements in the way we measure "lipids" or fat content in zooplankton (tiny planktonic animals) and other species. Zooplankton are an important food source for commercial fish, crabs, whales, and sea birds. Zooplankton that have higher fat content are a better food source than lower fat content prey. When lipid-rich prey are available, predators potentially gain more weight themselves and have a greater chance of surviving an Alaska winter.

Studying lipid content in snow crabs. In a Newport Laboratory experiment, juvenile crabs grown under warmer temperatures had higher growth rates but had lower rates of lipid energy stores (stored less fat) compared to crabs grown at colder temperatures, which may affect growth and survival rates.

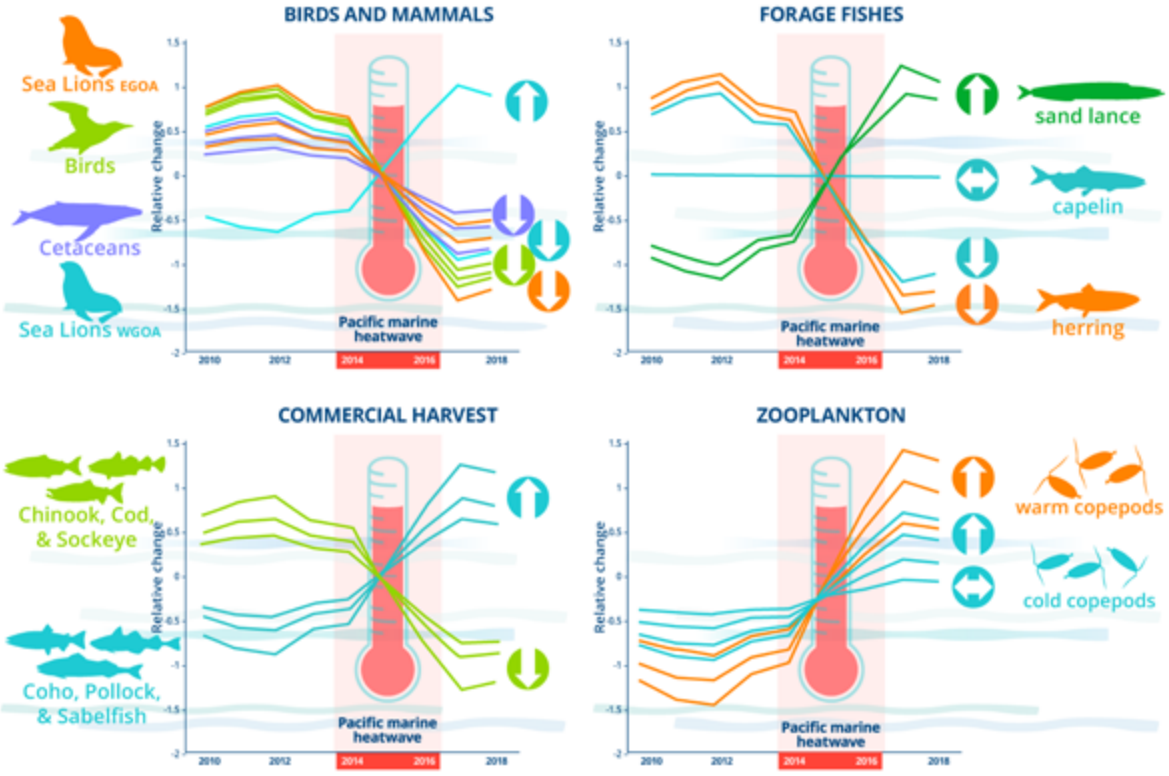
Scientists in our Resource Assessment and Conservation and Engineering Division also developed a new tool, a fat meter, to measure fat.

Marine Mammal Laboratory staff identified over 2,000 walleye pollock otoliths in northern fur seal diet samples. Resource managers require information on other species nutritional needs so they can account for this when setting annual fishing quotas.

The Alaska Fisheries Science Center's Fish Food Habits Laboratory provided important diet information that was used in assessing stock condition for commercially valuable fish and crab stocks. For example, Pacific cod stock declines during the Gulf of Alaska marine heatwave were largely influenced by poor feeding conditions. Lack of prey is also believed to be a contributing factor in the dramatic decline of snow crab in the Bering Sea in 2021. Having a record of diet information and feeding habits was important in understanding this and making sustainable management recommendations. In total, scientists analyzed over 8,000 stomachs, adding to our understanding of trophic interactions and food web dynamics in Alaska ecosystems. This information has long been a cornerstone for our stock assessments, ecosystem status reports and climate modeling projects.



Ecosystem Status Reports



The aftermath of the 2014-2016 marine heatwave in the central Gulf of Alaska showed winners and losers, slow recovery for some, rapid recovery for some, and little impact on others.

Gulf of Alaska Ecosystem Status Report

The Gulf of Alaska has been in transition since the 2014–2016 and 2019 marine heatwave periods. During this time some marine populations have decreased and others have increased. Average 2021 ocean temperatures indicate moderate conditions for growth and development for the main groundfish species.

There were mixed trends in the groundfish prey base in 2021. Zooplankton had below-average to average biomass that varied spatially across the Gulf. Our spring and summer zooplankton surveys observed lower large copepod biomass in the western Gulf, average in the central Gulf, and above average in southeast Alaska's inside waters (Icy Strait).

In general plankton-eating groundfish (i.e.,Pacific ocean perch, juvenile pollock, northern rockfish) had below-average body condition. Some plankton-eating seabirds breeding success was lower. This suggests lower production at the base of the food web and reduced prey base for planktivorous groundfish.

Forage fish like herring had above average abundance in 2021. So there was more food available for fish-eating groundfish (i.e., Pacific cod, arrowtooth flounder, sablefish, some rockfish) and fish-eating seabirds (i.e., common murres, puffins).

Groundfish apex predators such as adult Pacific cod, arrowtooth flounder, and Pacific halibut remain reduced in abundance (although sablefish has been increasing). Salmon harvest improved from the lows of 2020, largely driven by increased abundance of pink salmon.

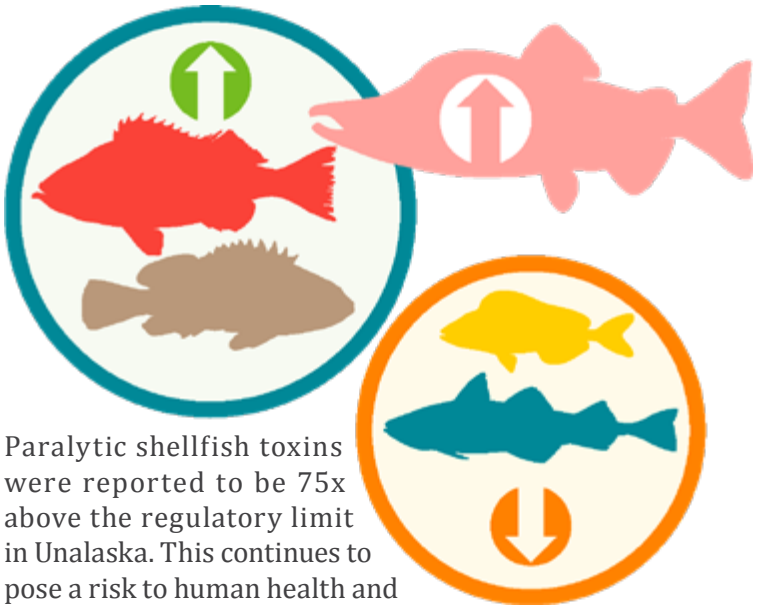
This report was used to inform 14 groundfish stock assessments for Gulf of Alaska stocks, and one statewide stock (i.e.,sablefish) in 2021.

GOA ESR Brief | GOA ESR full report

Aleutian Islands Ecosystem Status Report

In general, the Aleutian Islands' environmental conditions were near-average over much of the year. The Aleutian Islands have experienced sustained warm conditions since 2013. Cumulative effects include increased food requirements for groundfish, which tend to grow faster under warm conditions, changes in availability of nutritious prey, and faster growth rates for zooplankton. In 2021, both plankton- and fish-eating seabirds breeding rates were above the long-term average, suggesting wide availability of prey.

Eastern Kamchatka pink salmon abundance was the second highest on record. In years of high pink salmon abundance, we tend to see increased competition for prey and effects across the marine food chain. The combined biomass of Pacific ocean perch and northern rockfish is now higher than that of Atka mackerel and pollock, which used to be the dominant pelagic foragers.



Paralytic shellfish toxins were reported to be 75x above the regulatory limit in Unalaska. This continues to pose a risk to human health and food webs in the region.

This report was used to inform 7 groundfish stock assessments for Bering Sea/Aleutian Island stocks, and one statewide stock (sablefish) in 2021

AI ESR brief | AI ESR Full Report

Eastern Bering Sea Ecosystem Status Report

The eastern Bering Sea has been in a persistent warm phase since around 2014.

Sea surface temperatures in 2021 were higher than the average from 1985 to 2014. Temperatures near the seafloor in northern Bering Sea coastal waters, including Norton Sound, were very warm. There was a small area of cold water (i.e., the "cold pool") to the southwest of St. Lawrence Island. In 2021, the size of the cold pool was the fourth smallest on record. The southern shelf had moderately warm bottom waters.

Fall 2020 sea ice formation was delayed due to warm ocean temperatures. Different sea ice thickness between the northern (thicker) and southern (thinner) regions resulted from opposing wind patterns (i.e., whether the wind was blowing from the north or the south).

Cumulative years of sustained warm conditions may have contributed to declines in snow crab abundance, declines in Arctic-Yukon-Kuskokwim adult salmon runs, and seabird die-offs and reproductive failures in the northern Bering Sea region. In contrast, the Bristol Bay sockeye run was the largest since 1963.

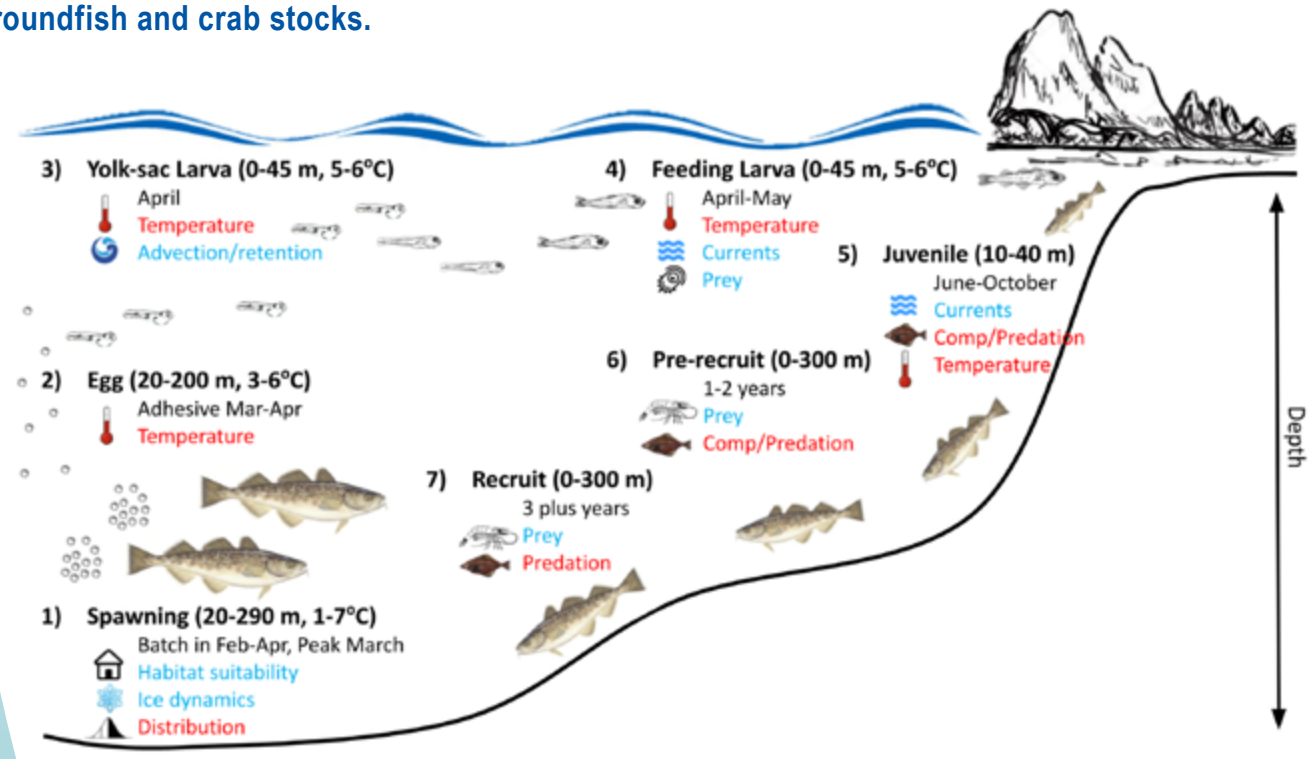
Species and fisheries have shifted distributions in response to oceanographic conditions. Between 2014 and 2019, the center of gravity for the groundfish community shifted to the north and into shallower water. Between 2019 and 2021, the distribution of species shifted back to the southeast.

This report was used to inform 7 groundfish stock assessments for Bering Sea/Aleutian Island stocks, and one statewide stock (sablefish) in 2021.

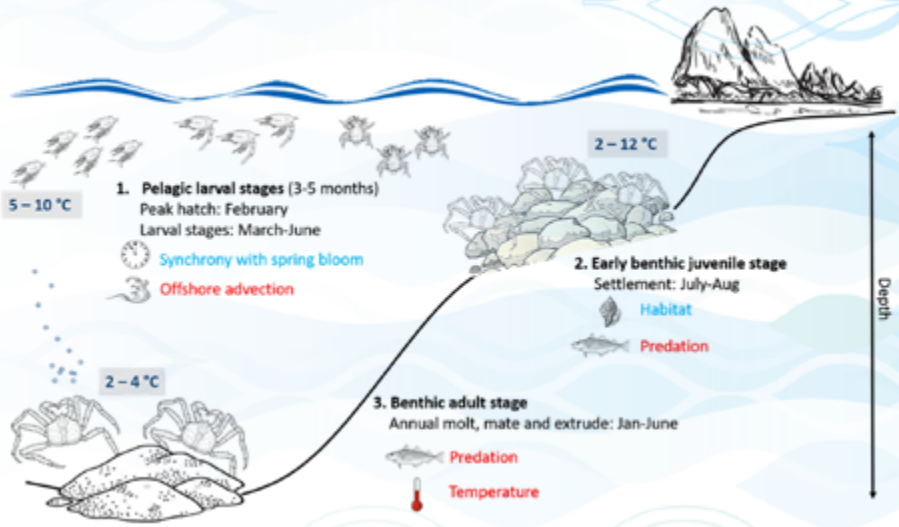
EBS ESR Brief | EBS ESR Full Report

Ecosystem and Socio-Economic Profiles

The ecosystem and socioeconomic profile or ESP is used to identify the potential environmental factors that affect individual fish and crab species survival that are considered when determining stock status. The ESPs provide a distilled stock-specific version of the broader ecosystem and socioeconomic landscape (in the Ecosystem Status Reports and Socio-Economic Status reports) that can be used at multiple decision points in the fisheries management process (contextual advice, data training, and model integration). Multiple ESPs are produced and updated each year at the Alaska Fisheries Science Center for both groundfish and crab stocks.



In 2021, our scientists developed a working conceptual Ecosystem and Socioeconomic Profile model of Eastern Bering Sea Pacific cod stock showing various indicators impacting the Pacific cod populations. Credit: NOAA Fisheries



Conceptual diagram of phenological information by life history stage for Bristol Bay red king crab and processes likely affecting survival in each stage. Thermal requirements by life history stage were determined from RKC laboratory studies.

New Ecosystem and Socioeconomic Profiles

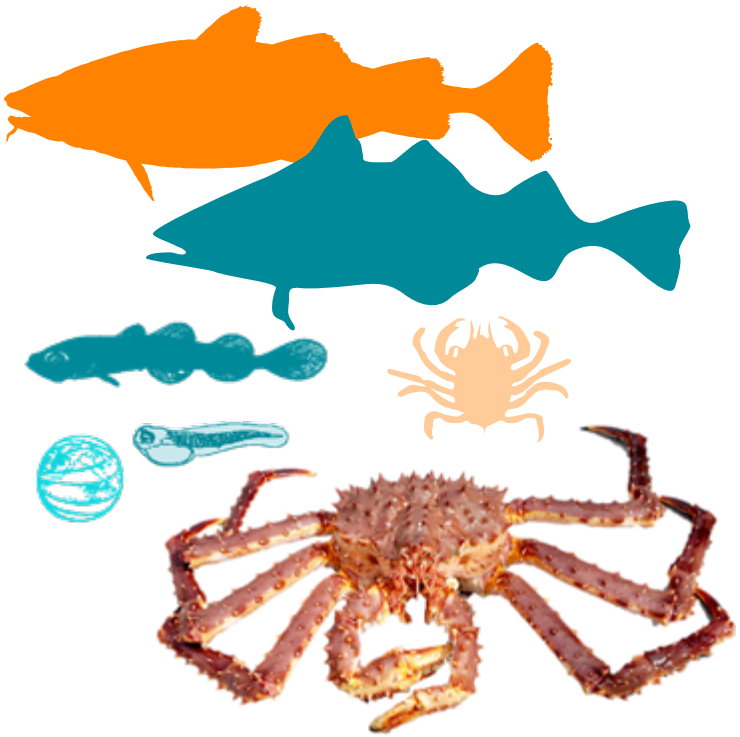
At the request of the North Pacific Fishery Management Council, a team of scientists produced the first ESP for the Gulf of Alaska and eastern Bering Sea Pacific cod stocks.

In the Gulf of Alaska Pacific cod ESP, scientists noted the lasting impacts of the marine heatwave on habitat suitability, and bottom temperature conditions on Pacific cod. The potential lag in continued bottom temperature warming post-heatwave can be detrimental to Pacific cod. There was also a strong indication of regional differences in conditions for Pacific cod. Socioeconomic indicators point to declining prices and ex-vessel values for Pacific cod participants. In the eastern Bering Sea Pacific cod ESP, there has been slight cooling on the surface, but still overall the surface remains very warm. Delayed freeze up and opposing wind patterns suggest that ice advance was likely low. This has been the case over the past several years. However, ice retreat was closer to average. Body condition measured through length-weight relationship of juvenile and adult Pacific cod remained near average. This suggests that there were sufficient prey resources. The population center has moved slightly southwest from the previous year but remains very north overall. Economic indicators remain above average.

A new Request For Indicators (RFI) process will be starting in spring 2022. We will use the data gaps and research priorities from the ESP and Stock Assessment and Fishery Evaluation reports to outline the ecosystem and socioeconomic indicator needs for different fish and crab stocks. The first draft RFI document was created for EBS snow crab and presented to the Crab Plan Team in September for review and feedback. A new ESP for EBS snow crab is scheduled for May 2022.

Annually Updated ESPs

Each year, existing ESPs are updated using the report card format. This is a shortened version of the full ESP report. It only includes basic element updates for the current year. These report cards are prepared during the annual harvest specification process starting in September for crab stocks and November for groundfish stocks. These ESP report cards are generally included as appendices to the main Stock Assessment and Fishery Evaluation report. ESP report cards were produced for Alaska sablefish (pg. 198), GOA pollock (pg. 90), GOA Pacific cod (pgs. 161 and 207), EBS Pacific cod (pgs. 347 and 395), and Bristol Bay red king crab.



Upper Left: Cooler with water sample bags. **Left:** Auke Bay Laboratories' Genetic Program staff working with autosampler to extract eDNA from water samples collected during 2021 survey at Amalga harbor. **Above:** Amalga eDNA sampling site.

Genetics Research Update

Our Genetics Program has three major focal areas: genetic analysis of salmon bycatch, environmental DNA, and population genomics of assessed species.

FY21 was a transition year for bycatch analysis as we moved to a more efficient genotyping chemistry and analytical approach. We successfully determined the genetic origin for over 20,000 Chinook, sockeye, and chum salmon. We used genetic stock identification from these salmon to understand stock-specific impacts of salmon bycatch. We presented updated results on stock-specific impacts of bycatch to resource managers at the North Pacific Fishery Management Council meeting in April and completed three reports describing our findings.

The change to a new chemistry and analytical approach is facilitating faster sample turnaround. This is allowing us to present chum salmon results nearly a year earlier than previously possible. We will be presenting results on chum salmon bycatch at the June 2022 NPFMC meeting. This will allow the fishing fleet (for the first time) to use data from the previous year to inform fishing strategies to minimize bycatch.

In 2021, we successfully completed our first eDNA study using metabarcoding. This technique allows us to identify many species within a single sample. We investigated the influence of habitat and tide on nearshore fish communities near Juneau. We found that habitat influenced results significantly. However, the effect of the tide was more subtle and habitat-specific.

In 2021, eDNA samples were taken on the Northern Bering Sea survey and two nearshore surveys in the Gulf of Alaska. Additionally, we conducted a study to determine the detection rate of eDNA using salmon pens as a control. We plan to publish this study in 2022 and present results from other samples taken in 2021. We are also planning to collect eDNA samples on a number of surveys including a deep sea coral and sponge survey and the Gulf of Alaska bottom trawl survey.

We conducted a number of population genomics studies in 2021 that informed management of assessed species. We analyzed samples of sablefish from the Bering Sea and Gulf of Alaska with whole genome resequencing and found no differences between the locations. This suggests that mixing and interbreeding occurs between these regions. We also included outgroups of adults from the Washington coast and juvenile samples from bird surveys on the Aleutian Islands. Again, no genetic differences were observed between the areas. We also analyzed samples of blackspotted rockfish from the Gulf of Alaska and Aleutian Islands and found no genetic differences. These findings were discussed with stock assessment authors and presented at the North Pacific Fishery Management Council Plan Team Meeting. In 2022, we will be analyzing data from additional species including Pacific ocean perch and other rockfish, pollock, and Pacific cod.

Economic and Social Science Research in 2021

Our economic and social science research team were instrumental in providing the foundational science to document the economic impacts of the COVID-19 on Alaska fisheries, communities, and businesses during 2020 and 2021.

We led regional and national level analyses of seafood trade and trade policy. We also documented the sustained economic contraction of the U.S. commercial fishing sector beginning in 2019 Quarter 1 through 2020 Quarter 2. These rigorous scientific analyses helped build support for Congressional action to support the affected industry.

In 2021, the Secretary of Commerce announced the allocation of an additional $255 million in Cares Act funding to states and territories from which Alaska, Washington, and Oregon received nearly $93.5 million. The USDA also added an additional $50 million to their Seafood Processors Pandemic Response and Safety (SPRS) Block Grant Program, of which Alaska, Washington, and Oregon received nearly $35 million in 2021.

In 2021, we conducted 343 socioeconomic surveys from Alaska fishing participants and businesses. We also conducted community assessments of groundfish and crab fisheries participation and social vulnerability through our new Annual Community Engagement and Participation Overview (ACEPO) Report. This report summarizes the participation of shoreside and at-sea communities in North Pacific Groundfish and Crab fisheries. It also provides in-depth snap shots of several highly engaged fishing communities.

Economic Summary of the Alaska Commercial Groundfish Fisheries in 2020

The ex-vessel value of all Alaska domestic fish and shellfish catch, which includes the amount paid to harvesters for fish caught, and the estimated value of pre-processed fish species that are caught by catcher/processors, decreased from around $2.0 million in 2019 to about $1.5 million in 2020.

The 2020 total groundfish catch decreased by 4.6 percent. The total first-wholesale value of groundfish catch decreased by 17 percent, relative to 2019. Much of the decline in values was associated with COVID-19 impacts on supply chains and demand changes. This is especially true for those products with significant exports to China for reprocessing and those where food service constitutes a significant portion of the end market.

The groundfish fisheries accounted for the largest share (54 percent or $811 million) of the ex-vessel value of all commercial fisheries off Alaska. The Pacific salmon fishery was second with just over $377 million or 25 percent of the total value.

The ex-vessel value of the shellfish fishery amounted to around $235 million or 16 percent of the total for Alaska. It exceeded the value of Pacific halibut which was about $70 million or 5 percent of the total for Alaska.

Economic SAFE data

Development of Community Economic Impact Model for Southwest Alaska Fisheries

Most traditional regional economic models developed for North Pacific fisheries depict either the whole state (i.e., Alaska) or a large sub-region (e.g., the Southeast region). While these models are well suited to calculate the economic impacts of fishery management actions on those relatively large regions, they may not as accurately represent impacts on smaller "fishing communities," or fishing-dependent areas such as individual boroughs or census areas (BCAs). Therefore, results from traditional models may be less useful for fishery managers, policy makers and other entities interested in examining impacts on specific communities, especially ones with very unique, fishing-dependent economic structures. No existing study has yet developed models designed to estimate impacts on individual fishing-dependent communities in Alaska.

To address this problem, AFSC's Economic and Social Science Research (ESSR) program recently constructed a 10 region multi-regional social accounting matrix (10MRSAM) model for the Southwest Alaska (SWAK) fisheries based on the surveys of seafood industry and other supplementary information. The ten regions include six SWAK BCAs, the rest of Alaska, West Coast, and the rest of U.S. The development of the 10MRSAM model represents a significant advancement of science for Alaska fisheries because the model enables examination of the economic impacts for individual fishing-dependent communities or BCAs.

Based on the 10MRSAM model, an ESSR economist (Chang Seung) and an AKRO economist (Scott Miller) conducted a project to develop a web-based software application that the analysts, without in-depth knowledge of regional economic models, can use to estimate the economic impacts of fishery management actions or environmental shocks (such as climate change). Development of the user-friendly software is complete while the supporting documents (tech memo and user manual) will be in 2022.

Software Model

Social and economic research related to climate change and resilience

Social scientists and economists have also been working to understand climate change impacts on fishermen, their response strategies, how changing fish distributions may affect fleet distributions, and the cumulative economic impacts of those changes across Alaskan communities.

Fishermen across the Gulf of Alaska have been working with Center social scientists to understand how to ensure their own resilience in the face of climate change impacts on their fisheries. Through interviews and workshops, fishermen and scientists have been engaging in conversations about ecological changes, responses to those changes, and what fishermen and the fishing industry need to build resilience into the future. The work has led to presentations at scientific conferences and to fishing organizations, hearings within the Alaska State legislature on climate impacts on fisheries, media coverage in national fishermen's journals, and collaborations with industry to develop tools for bridging pathways between fishermen and scientists to communicate and provide input into climate science.

Supporting Resilient Bering Sea Communities under Conditions of Social-Ecological Change

The Effects of Environmental Change on Yukon Salmon and Alaska Fishing Communities

The Alaska Fisheries Science Center and partners are seeking to better understand ecosystem changes in the Bering Sea and how these changes are affecting communities who participate in subsistence and commercial salmon fisheries. Salmon fisheries in the Yukon-Kuskokwim Delta are in serious decline, directly affecting community

wellbeing, food security, and socio-cultural relationships. The last few summers the Yukon salmon fishery saw record low runs resulting in a closed commercial fishery, and Yukon River families were not able to fish for subsistence. The U.S. Secretary of Congress declared fisheries disasters in 14 Alaska fisheries including the Yukon-Kuskokwim Delta salmon fisheries (in 2020 and 2021). Our research focuses on how people are affected by and respond to these declines. This work is part of the The Alaska Climate Integrated Modeling Project on ecological effects of climate change in the Bering Sea, including warming seas, reduced sea ice, and increased storms, among others. The aim is to bring these voices from western Alaska together as a record of people's experiences and adaptations to climate variability.

Climate Change and Fishing Participation in the Norton Sound Red King Crab fishery

This project examines the sustained participation in Norton Sound Red King Crab (NSRKC) fisheries and the effects of environmental change on the fishery and community dependency. In the Northern Bering Sea region, climate change effects include warmer water temperatures, reduced sea ice, coastal erosion, and increased storm events. These changes are directly affecting the timing, stock condition, and harvest patterns of crab fisheries. Due to declining stocks, the North Pacific Fisheries Management Council placed community protection measures on Norton Sound Red King Crab fisheries. However, the stock continues to decline affecting communities reliant on both commercial and subsistence fisheries. In addition to direct harvest, Norton Sound has an active crab processing plant in Nome, which provides employment. Importantly, there is a strong reliance on subsistence harvest of marine resources including crab species for food security and social cohesion.

Local and Traditional Knowledge

There is increasing recognition of the importance of incorporating diverse knowledge systems to create resilience socio-ecological systems. Social scientists at the Center have been conducting research with fishermen and traditional knowledge holders to understand how to incorporate local and ecological knowledge into North Pacific fisheries management. In the Gulf of Alaska this work has led to a successful interdisciplinary proposal from scientists and fishing organizations. The proposal promotes information exchange, including through the use of an application developed by fishermen to provide real-time ecological observations.

In the Bering Sea and Arctic there are several ongoing projects focusing on Local Knowledge and Traditional Knowledge and Subsistence information.

Multiple Ways of Knowing the Bering Sea Ecosystem: Indigenous Conceptual Models

Part of the PICES working group #44: Joint PICES/ICES Working Group on Integrated Ecosystem Assessment (IEA) for the Northern Bering Sea - Chukchi Sea. Indigenous Peoples have been thriving in the Bering Sea ecosystem for millennia, practicing inherent sovereignty through relationships-based approaches. Climate change is directly affecting marine ecosystems in this region including rural coastal communities. Indigenous knowledge has long worked to mitigate various shocks/disruptions to the holistic and interconnected system. Despite this depth of proven experience and knowledge, there remain challenges to including multiple ways of understanding ecosystem processes into assessments and management processes based on western science. Indigenous Conceptual Models are one way to illustrate ecological well-being, showing what has sustained people and their ecosystem through time and change. Integrated ecosystems assessments have relied heavily on western science and quantitative data to inform ecological models. Due to their narrow focus and limited methodologies, IEAs can miss critical ecological information, particularly elements that hold socio-cultural importance. The goal of this project is to include Indigenous Knowledge in the IEAs and similar efforts to reflect Indigenous ways of understanding.

Other Sociocultural Research

The Effects of the COVID-19 Global Pandemic on Alaska Fishing Communities

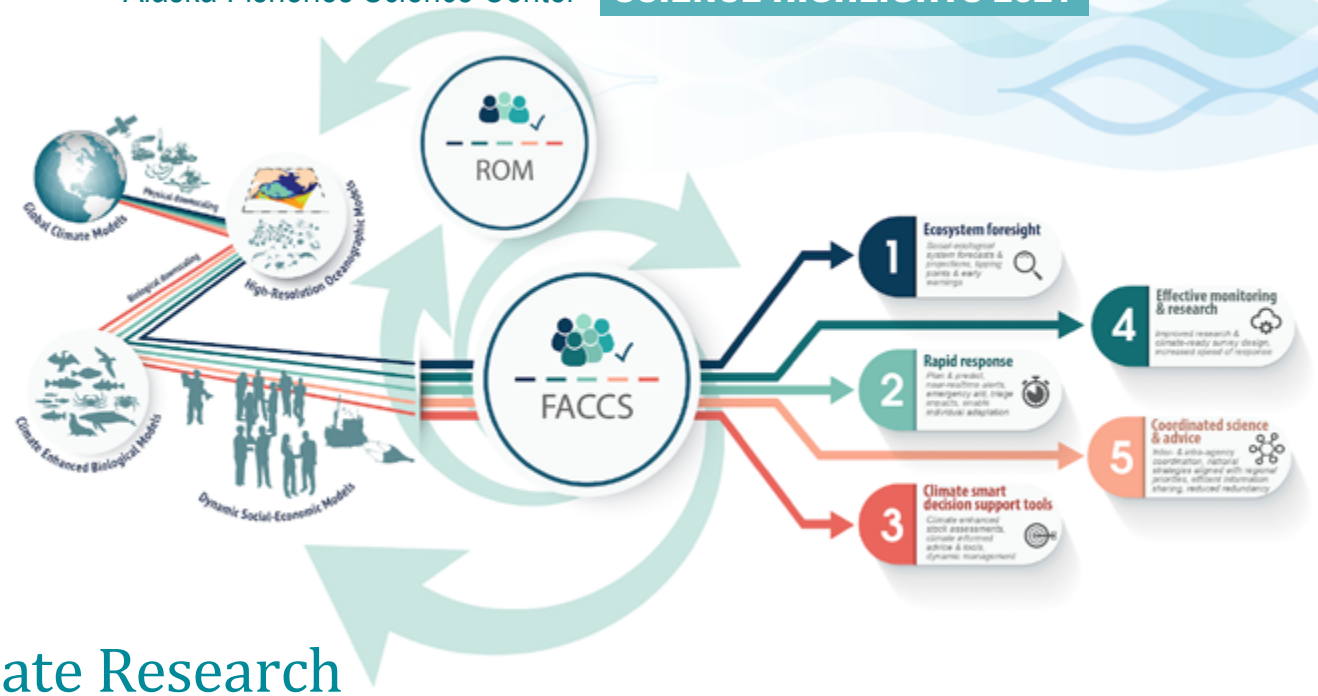
Social scientists have also been conducting a variety of other research related to the COVID19 pandemic, fisheries disasters, and generational turnover on Alaskan communities and fisheries participants. Throughout 2021, social scientists conducted interviews with fisheries participants.

We are hoping to understand the well-being impacts of the pandemic and the effects of coping strategies that fishermen and Alaskan community members more broadly had invoked including on food security, livelihoods, and the social fabric of communities.

Social scientists also interviewed key experts on fisheries disaster planning and its evolution in the face of increasing disaster requests and lessons learned from allocations of CARES Act funding. The aging of fishing participants ("graying of the fleet") is increasingly documented in Alaska and elsewhere in the country and could ultimately present a food security problem if aging participants are not replaced in fisheries. Social scientists also are documenting the issues faced by new entrants into fisheries across the country. They conducted key interviews with experts who are developing programming to address these issues.

Beyond Recreation: When Non-Commercial Fishing Motivations are more than Sport or Pleasure

The Magnuson-Stevens Fishery Conservation and Management Act directs NOAA Fisheries to manage commercial and recreational fishing as separate activities. Yet, numerous studies in the U.S. have demonstrated this distinction is not clear-cut in practice. In addition, policy definitions do not adequately cover other important concepts in the region. Social scientists are conducting a study to describe and characterize fishing activities across US regions that are not clearly recreational (such as customary exchange, where the purpose is not sport or pleasure). The goal is to provide policy/management insights about these non-commercial activities that are central to local fishing communities. The outcome of these efforts begins to identify the relevance of these ideas nationally. It will also identify information needs that can guide future coordinated social science research across regions.



Climate Research

For the past several years, we also have been conducting various studies and projects to better understand the impacts of climate change on Alaska marine life.

This year we announced our efforts to support a new national NOAA Climate and Fisheries Initiative; progress on regional climate modeling work for the eastern Bering Sea and Gulf of Alaska; and new climate Regional Action Plans for the Gulf of Alaska, Bering Sea, and Arctic.

Our scientists supported climate discussions at the Cop26 UN Climate Summit in October. Dr. Anne Hollowed was part of an international team of 200 scientists who worked on the first Marine Ecosystem Assessment for the Southern Ocean (MEASO) that was presented during Cop26.

CLIMATE INFORMED MANAGEMENT

Through the national Climate and Ecosystems Initiative, NOAA is building a nationwide ocean modeling effort to provide climate-informed ocean forecasts to support dynamic management decisions. The goal is to help reduce risks and increase the resilience of resources and the people that depend on them. In Alaska initial funding in 2021 supported pilot projects and development of the Arctic Grid. Future goals include to

- Develop reliable ocean modeling products informed by a suite of existing and expanded surveys (funded through a separate initiative).
- Open the door for managers to be able to look at species-specific, climate-enhanced assessments that do not rely on a single season or location (e.g., ocean conditions in spawning areas or season) and can be used to avoid bycatch and protected species interactions.
- Develop short-term forecasts to improve rapid responses for planning and prediction, alerting constituents, triaging impacts, and enabling adaptation. Fisheries managers are already benefiting from some pilot applications of climate-enhanced models in the Bering Sea. The Climate and Fisheries Initiative will facilitate the operationalization of these pilot projects. It will also provide expanded support for development of these tools in the Gulf of Alaska and Arctic.

Alaska Climate Integrated Modeling Project

Through the continued work of the Alaska Climate Integrated Modeling Project (ACLIM), which began in 2019, we hope to address resource managers' climate information needs by providing the best available science and tools. ACLIM scientists want to help resource managers, fishermen, and subsistence and coastal communities anticipate how climate change may affect them and know what responses may reduce impacts and promote resilience.

We take information from global climate models to produce regional models that can be used to help predict future impacts at finer scales. The hope is to reduce climate impacts and provide new opportunities for fishermen and communities to increase their resilience to changes like sea level rise and fluctuating marine populations. In the long-run, the goal is to have environmental decision-making that involves stronger partnerships between local communities and scientists.

To help resource managers anticipate what to expect and how to determine the most appropriate response to changing environmental conditions in the eastern Bering Sea, we are

1. **Providing** projections of physical and ecological conditions under different levels of climate change (levels of global carbon mitigation).
2. **Evaluating** the effectiveness of adaptation actions including those supported by fisheries management.

By combining physical and oceanographic models with socio-economic models, we want to develop more realistic models. The project team is seeking broader public input to inform their understanding of socio-economic responses to changing environmental conditions (e.g., estimate the catch, environmental impacts, revenue, profit, and impacts on fishing communities under different climate scenarios). With this information, resource managers will be able to more effectively evaluate the tradeoffs of various management actions.

Gulf of Alaska Climate Integrated Modeling Project

The Alaska Fisheries Science Center in partnership with the University of Washington and NOAA Research's Pacific Marine Environmental Laboratory kicked off a new climate modeling effort in the Gulf of Alaska (GOACLIM). Based on the ACLIM project, this multi-model approach includes an ECOPATH model, multispecies models, and an Atlantis ecosystem model for the Gulf of Alaska. It will include fleet dynamics, a marine mammal project looking at marine heatwave impacts on Steller sea lions, a sociological study of adaptive capacity in fishing communities, and combining economic models for southwest Alaska. These economic models include a computable general equilibrium model for GOA and other (?) models.

Alaska' Climate Regional Action Plans

In 2015, the NOAA Fisheries Climate Science Strategy was published as a guide for efforts by NOAA Fisheries to address information needs across seven science objectives that address the Nation's challenges in sustaining and managing large marine ecosystems in the face of a changing climate. We developed Regional Action Plans for the eastern Bering Sea and Gulf of Alaska. The focus of these plans was to monitor marine ecosystems, conduct process studies to better understand marine food webs and species relationships, and develop reliable predictive models. We expected that research on climate change and fisheries would evolve over time and thus periodic updates of these plans would be necessary. Upon completion of the NOAA Fisheries Climate Science Strategy five-year review, NOAA Fisheries leadership concluded that an update of the RAPs was both timely and necessary. So, we drafted a Gulf of Alaska Regional Action Plan (GOA RAP 2.0), an Eastern Bering Sea Regional Action Plan (EBS RAP 2.0) and a new Regional Action Plan for the Arctic.

The purpose of the Regional Action Plans is to identify and describe planned and proposed in climate-science research activities at the Alaska Fisheries Science Center during the years 2022–2024.They also highlight new initiatives and projects that require additional funding but could be implemented quickly to build on the portfolio of climate-related research.

Gulf of Alaska Regional Action Plan

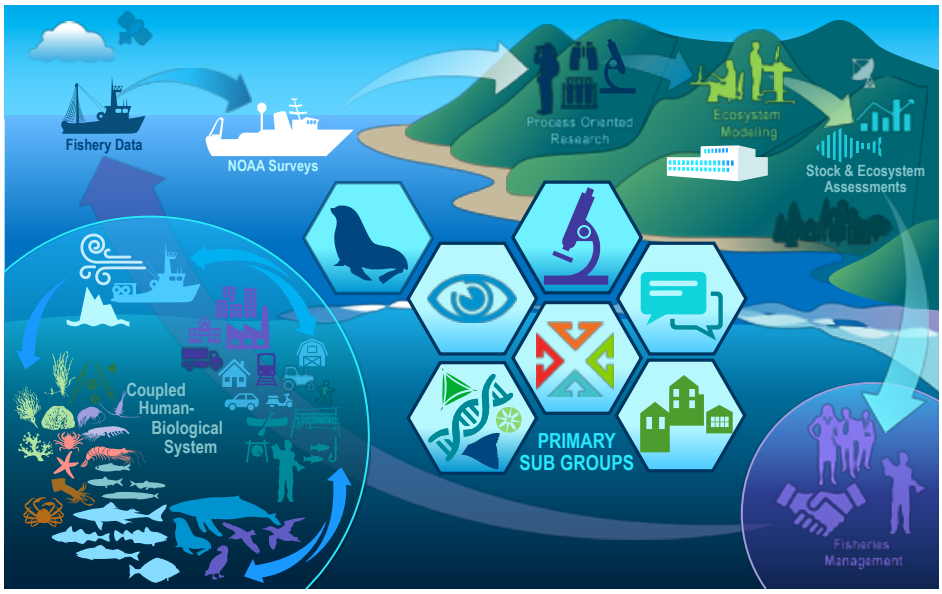
In 2021, we rolled out a three-year Regional Action Plan 2.0 for the Gulf of Alaska. It builds off the initial plan for the Gulf of Alaska produced in 2016. Some highlighted projects include

- Developing new methodologies for efficient and rapid assessment of key metrics (fish condition, relative abundance) to reduce lags in use in fisheries management.
- Conducting experimental studies on the effects of increasing temperature and ocean acidification.
- Climate vulnerability analysis for the Gulf of Alaska.
- Assessing heatwave impacts on Steller sea lions.

- Developing a coupled fleet-community-adaptation model.
- Developing Long-Term Pathways to Incorporate Stakeholder Local Ecological Knowledge into the Gulf of Alaska Science Advisory Process

Eastern Bering Sea Regional Action Plan

The Eastern Bering Sea Regional Action Plan (RAP 2.0) updates 51 current and lists new (started after 2016) climate research activities likely to occur in the next 3 years and provides an evaluation of remaining key scientific gaps.



The plan emphasized the need to continue support for projects that advance ecosystem advice in tactical decision making in the regulatory process. Scientists also identified the need for projects focused on better understanding shifting spatial distributions through further tagging studies and collaboration with Russia.

The plan identifies research gaps including:

- Data on phytoplankton bloom timing, seasonality, and phytoplankton and zooplankton species composition (measurements are strongly linked to overall fisheries production).
- Impacts of climate change on habitat use and prey resource distribution.
- Spatial and temporal coverage. Improving coverage and adding novel biogeochemical sampling will also require development of new tools and technology.
- Increase understanding of human community adaptations and non-market values of the Bering Sea ecosystem.
- Improve communications with fishing-dependent communities about the risks of climate change.

Arctic Regional Action Plan

This is the first Regional Action Plan for the Beaufort and Chukchi seas. It details several previous and ongoing research programs in the high Arctic including large-scale integrated surveys (RUSALCA, DBO, AEis, AIES). They may serve as baselines for assessing future changes. It also includes information on several previous marine mammal surveys that looked at abundance, migration, and trophic interactions.

The Arctic RAP identified 11 ongoing and expanded research activities that are important for ecosystem monitoring, synthesis, and management responses in the U.S. Beaufort and Chukchi seas. The research spans trophic levels and human components of the ecosystem and would occur from 2022 to 2024.

The areas of research include:

- Expand sampling for demersal communities within the Arctic (Distributed Biological Observatory)
- Develop and implement bottom trawl and acoustic-trawl surveys to detect northward distribution shifts of species in the Chukchi Sea.
- Predict harmful algal blooms (HABs) and juvenile snow crab status
- Predict overwinter survival of Arctic various cod species
- Renew the Arctic Ecosystem Status Report
- Expand trophic and spatial models for Arctic systems
- Develop and maintain cetacean sampling in the Chukchi Sea
- Identify trophic roles of ice seals in the Chukchi and Beaufort Seas
- Improve the bridging of knowledge to inform Arctic management
- Develop communications to support co-producing science with Arctic Communities
- Convene the Local Knowledge/Traditional Knowledge and Subsistence Taskforce for Arctic Region

Mariculture and Aquaculture-Related Research

The Governor's Mariculture Task Force set the goal of developing a $100 million mariculture industry in Alaska State waters in 20 years. This would be achieved through

- Workforce development.
- Investment in or adaptation of seafood processing, hatchery, and harvesting infrastructure.
- Research and development of current and new mariculture species and products, and
- Regulatory changes.

At present, mariculture in Alaska is only taking place in state waters. The main regions of mariculture development in Alaska currently are Southeast and Southcentral (Prince William Sound, Kenai Peninsula, and Kodiak).

NOAA Fisheries involvement in mariculture research is important given the potential for impacts (both positive and negative) to wild fish populations' Essential Fish Habitat, other commercial and recreational fisheries, subsistence intertidal and subtidal harvest, marine mammals, and other uses of the coastal zone.

In order to accomplish the triple bottom line of sustainable mariculture – environmental, economic, and social sustainability – communication and collaboration across diverse partnerships will be critical. These partnerships include federal and state agencies; non-governmental and nonprofit organizations; Alaska Native communities; corporations; and governments, universities, growers, hatcheries, and any other groups involved in the use or management of the coastal zone.

The Alaska Fisheries Science Center is developing a mariculture research plan to be released in 2022. The focus of the plan is on shellfish (Pacific oysters, pinto abalone, king crab), other invertebrates (sea cucumber), and algae (kelp and red algae).

FY21 Accomplishments.

- Completed pilot studies of the effects of sound on Pacific herring. Work will continue in 2022 on strategies to deter herring from spawning on mariculture infrastructure, using the Little Port Walter facilities.
- Completed a prototype to grow the red algae, dulse (*Palmaria mollis*), in classrooms for mariculture education. The first deployment of the system will be in a classroom in Klukwan as part of the Chilkat Indian Village Tlingit language and culture camps.
- Began monitoring efforts with local Juneau oyster farm, Salty Lady Seafood, to better understand the relationship between oyster toxicity levels, harmful algal blooms, and environmental conditions.
- Using historical and modern maps to investigate spatial patterns of kelp canopy change in Southeast Alaska since 1915.
- Worked with our Genetics Program and kelp growers to improve understanding of the population genetic structure of kelp species under cultivation, and to assess potential genetic risks to neighboring wild populations.
- Supporting the Sea Grant-led effort to develop a Research and Training Center. Its intent will be a platform to bring together researchers (government and academia), regulators, industry, and coastal communities to coordinate on funding opportunities and generally enhance communication among these groups for common goals.

Fisheries Monitoring and Analysis

In 2021, commercial fishery observers were deployed for 34,460 days in the Bering Sea, Aleutian Islands, and Gulf of Alaska, representing the largest observer program in the nation.. In addition to fisheries data collections, observers recorded essential information on protected resources including Steller sea lions, killer whales, harbor porpoise, and the endangered short-tailed albatross.

To collect this level of data and to provide it for the management of marine resources off Alaska, the North Pacific Observer Program conducted 94 observer preparation classes made up of six unique training types. Since many observers deployed more than once this year, staff provided training to a total of 852 observers.

In addition to fishery observers, we also run an operational electronic monitoring program on approximately 170 fixed-gear vessels. EM is the use of technologies – such as vessel monitoring systems or video cameras – to passively monitor fishing operations through video surveillance, tracking, and sensors. The fixed-gear EM program collects data on fishing location and catch. In 2021, we continued collaboration with the pollock fishing industry on the development of a new EM program on catcher vessels, accompanied by observer sampling at participating processing plants.

Participating vessels carry EM systems to confirm low or no discard at-sea, allowing observers to collect data needed for science and management at a shore-based processing facility. While these data collections occur at the trip level, rather than at the haul level as is done by observers at sea, this model may provide for more efficient use of observer resources, allow for more diverse sampling approaches, and increase safety at sea.

The largest costs of most electronic monitoring programs are manual video review, data transmission, and storage. Computer vision and machine learning applications, based on labeling datasets to train computers to, among other things, identify fish species in images, offer the potential of greatly reducing costs and decreasing image processing time. Currently, tools are being developed for processing imagery to identify catch events, with future applications for species identification, weight and length estimation, enumeration of fishing effort (e.g., counting hooks on a longline), or simply determining if a vessel is in transit or fishing (i.e., whether catch is on board).

As EM becomes increasingly integrated into fisheries monitoring, we will continue to work with the Pacific States Marine Fisheries Commission to investigate methods of automating the review of the collected images. Working with artificial intelligence and machine learning algorithms developed by the University of Washington as part of the EM Innovation Project, staff are seeking ways to detect, track, and identify catch events.

Gulf of Alaska Surveys

Winter Pre-Spawning Pollock Acoustic-Trawl Survey in Shelikof Strait and Marmot Bay

Shelikof Strait is an important spawning area for commercially-valuable Alaska pollock. It is located west of the Kodiak Island chain. We conduct an annual acoustic-trawl survey here and around the Shumagin Islands in the winter. We also conduct winter pre-spawning surveys in alternate years in the Bogoslof Island area (even years) and Kenai/ Prince William Sound (odd years). In 2021, we planned to survey Shelikof Strait, Chirikof Island shelf break, Marmot Bay, the Shumagin Islands, the Kenai fjords, and Prince William Sound. However, due to the pandemic and poor weather conditions, our efforts were restricted to just Shelikof Strait and Marmot Bay. The survey occurred March 2-15, 2021.

In 2021, in Shelikof Strait, we saw abundant young fish born in 2020 (these age-1s made up about 92 percent of the numbers of fish observed but only about 13 percent of the biomass or total weight). As in 2020, we saw a continued reduction in the relative abundance of the 2018 year-class (age-3s) compared to the amount seen in high numbers as age-1s during the 2019 survey. However, the

Allison Myers (A.I.S., Inc) and Scott Furnish (MACE) process a trawl catch aboard the NOAA Ship Oscar Dyson during the 2021 winter acoustic-trawl survey of Shelikof Strait and Marmot Bay.

2017 year-class (age-4s) was still relatively abundant as expected, as was the 2012 year class (age-9s). The maturity composition of females > 40 cm (n = 219) was 88% pre-spawning, suggesting the survey timing was appropriate in 2021. Overall, the total age 1+ biomass in Shelikof Strait in 2021 was 527,000 metric tons (t), which is 15% higher than that estimated in 2020. Pollock abundance in the Shelikof Strait acoustic-trawl survey indicated a similar relative abundance to what scientists in the Alaska Department of Fish and Game survey and

the Alaska Fisheries Science Center Gulf of Alaska bottom trawl and acoustic-trawl surveys saw in summer 2021.

The pollock biomass estimate for Marmot Bay was around 7,400 t. The Marmot Bay region is very small relative to Shelikof Strait, and has a much lower pollock biomass. The largest abundance of pre-spawning fish was found in Spruce Gully between the inner- and outermost transect lines. About 25 percent of the adult biomass (> 40 cm) was in pre-spawning condition (n = 19). The remaining female adults were developing or immature.

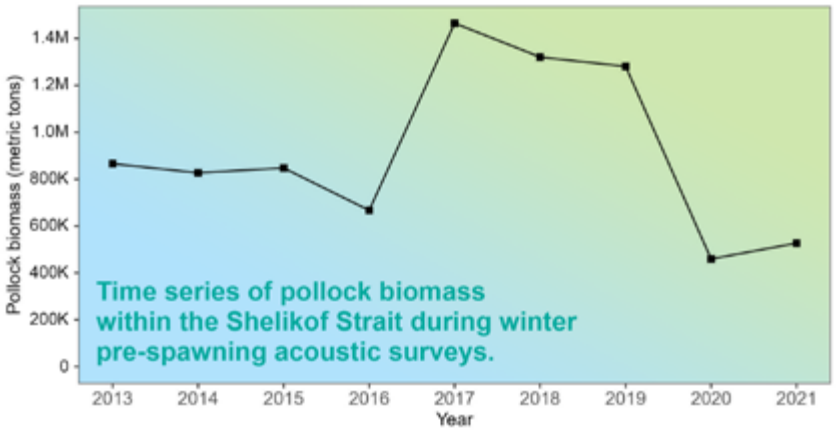
In Marmot Bay, about 17 percent of the biomass consisted of age-1 fish (2020 year class). However, the majority of the biomass (61 percent) was comprised of age-4 and older pollock. We were not able to survey the Marmot Bay area in 2020 due to COVID-19, but compared to 2019, survey biomass was slightly higher in 2021.

A summary of the 2021 winter Shelikof survey relative to 2020 showed:

- Age-1 pollock numbers and biomass were ~440 and 69 times higher, respectively.
- Pollock age-1+ biomass increased 15 percent.
- Pollock biomass for the 2012 year class decreased 10 percent (27 percent of total biomass).

A summary of the 2021 winter Marmot Bay survey relative to 2019 showed:

- Pollock age 1+ biomass increased 18 percent.



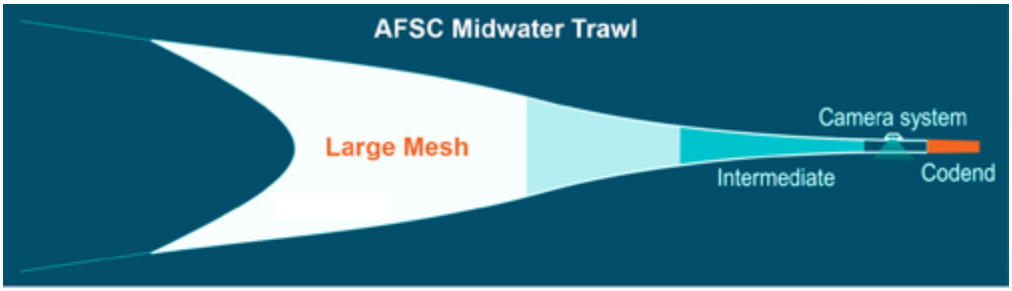
The Shelikof Strait area has been surveyed annually since 1981, but only observations since 2013 are shown.

The survey is led by our Midwater Assessment and Conservation Engineering Program. Scientists continued to apply innovative technological tools in 2021 that were developed in-house.

2021 Research Brief

Technological Innovations in Fish Surveys

In 2010, the Midwater Assessment and Conservation Engineering Program started developing the Camtrawl system, a survey device that enables species identification and size measurements to be extracted from stereo camera images taken within a midwater survey trawl. Since then, they have worked to use the data obtained by the system to partially replace or supplement trawl sampling, reducing the need to capture fish and sample them onboard the survey vessel. In 2021 winter and summer surveys, this system was used to capture over 1.2 million images at sea, improving estimates of fish abundance by providing fine-scaled information on fish and invertebrates observed on the acoustic echosounders. Another related emerging technology that was also designed in-house is the Lowered Stereocam for sampling seafloor habitats. This system will enable scientists to collect image data during an upcoming 2022 coral survey without disturbing this sensitive habitat.



Cook Inlet Beluga Whale Research

We conducted aerial surveys to estimate the winter distribution of beluga whales in November 2020 and March 2021. We also conducted a survey to estimate abundance and trends in June 2021. We fly the entire coast north of Augustine Island and cross the inlet. We then compared our observations with sound recordings collected from year-round moorings at set locations within the inlet. In August through September, we collected photographs to estimate age groups and generate an index of beluga calf production during this time. We covered 13,190 km, resulting in ~400 sightings of ~5,000 marine mammals.

We also conducted 25 flights using a hexacopter (unmanned aircraft system [UAS]) equipped with a high-resolution camera to photograph beluga groups. From the photographs, we measured individuals by estimating the distance from their blowhole to their dorsal ridge. We were able to classify whales as either a calf, juvenile, or adult based on their relative lengths. In 2021, we collected 2,483 overhead photos of Cook Inlet Beluga whales and an additional 2,871 photos from a support boat.

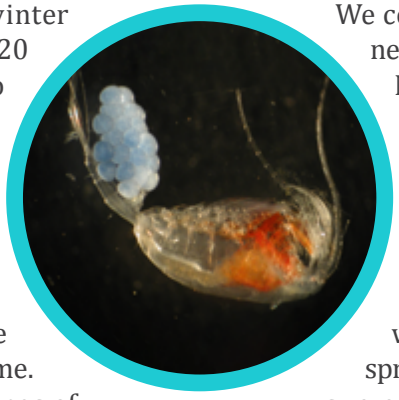
A total of 13,131 photos from the 2019 survey were examined for beluga images. Of these, 2,983 images were found to have beluga whales in them. There were 2,714 images that were high enough quality to be matched to existing identified whales or assigned a new ID. There are now 3,512 total Cook Inlet beluga ID photos (includes multiple photos of individuals) in our Marine Mammal Laboratory catalog.

From May to June and again from September to October, we collaborated with the University of Washington Cooperative Institute for Climate, Ocean, and Ecosystem Studies; the Alaska Department of Fish and Game; and the Bureau of Ocean and Energy Management to deploy passive acoustic recorders in Cook Inlet. The purpose was to identify feeding grounds for the endangered beluga whale population and to characterize potential noise-related disturbance. Recordings will also be used to identify year-round spatial habitat for other species such as harbor and Dall's porpoises, and killer whales. This project maintains 13 acoustic moorings and services them twice per year.

Beluga Whale Sounds Aid Scientific Understanding of When Whales are Hunting Prey

Research Brief

Western Gulf of Alaska Larval Fish Survey



We conduct this annual survey in partnership with NOAA Research's Pacific Marine Environmental Laboratory to monitor oceanographic conditions (e.g., temperatures, water density, nutrients, etc.), and planktonic animals (zooplankton) and larval fish abundance, growth and spawn timing. During 2021, we had to reduce the extent of the spring survey in May and cancel the fall survey. In the spring of 2021, the surface (0-5 m) and bottom (100-150 m) temperatures were relatively cool to average.

Overall, the spring zooplankton community resembled that of recent warm years. Large copepod abundance (>2 mm) was very low, similar to 2015 and 2019. Large copepods have higher lipid content (fat). Small copepods (>2 mm) were abundant throughout the survey area. Juvenile life stages of krill (>15 mm) had low abundance overall. However, abundant small copepods suggest a sufficient forage base for various species of late-stage larval fish. We caught Pacific sand lance at most stations across the study area at moderate levels.

For larval fish, we caught moderate to low levels of larval southern rock sole, northern rock sole, rockfish, and arrowtooth flounder, similar to catches we have seen in warm years in the Gulf of Alaska. However, for walleye pollock we observed record low abundance levels in our core survey area. We also observed an unusual distribution, with our highest catches offshore of Kodiak Island. Pacific cod were nearly absent from our core survey area in 2021, similar to 2015, 2019. Like pollock, the highest catches in 2021 were offshore of Kodiak.

Gulf Watch Alaska

NOAA Fisheries scientists continue to support the Gulf Watch Alaska long-term ecosystem monitoring program. This program is funded through the Exxon Valdez Oil Spill Trustee Council for the marine ecosystem affected by the 1989 oil spill.

This year during the spring survey, a massive algal bloom was detected in the upper 20 mm of the water column. Scientists verified that this was the highest chlorophyll concentration in the 24-year history of the survey along the Seward Line. Water temperatures were cooler overall,

but around the GAK1 mooring, which is located at 59° 50.7' N, 149°28.0'W within the Alaska Coastal Current, water temperatures were still warm versus the 50-year mean.

Seabird abundances were among the lowest in the survey time series. Scientists saw moderate numbers of large copepods. Age-0 sablefish growth was slightly below average. Age-0 sablefish are important food for auklets. Scientists saw a positive trend for sand lance, but still very few capelin were seen in 2020.

Gulf of Alaska and Bering Sea Longline Survey

This survey is conducted annually from June through August off a commercial fishing vessel and is designed to monitor sablefish and other groundfish population trends. Stations are spaced systematically along the continental shelf and upper slope and are sampled every year in the Gulf of Alaska, in even-numbered years in the eastern Aleutian Islands area and in odd-numbered years in the eastern Bering Sea. At each station, we typically sample depths from ~150 to 1,000 m. This year, we caught 169,613 sablefish and sampled 3,480 of these to estimate the age composition of the population. We also collected eyeballs from 60 sablefish to examine shifts in their diets as determined by stable isotopes incorporated into eye lenses from early age to adulthood. Since 2015, longline survey catches of sablefish have been increasing. The increases are mostly attributable to gains in the western Gulf of Alaska, eastern Aleutian Islands area, and the eastern Bering Sea.

We tagged 6,156 sablefish, 312 shortspine thornyhead and 27 Greenland turbot to learn more about their movements, behavior and habitat use. Thirty-one tagged sablefish were recaptured during the survey and an additional 369 sablefish tags were recovered in various fisheries. The greatest time at liberty was 15,423 days and the greatest distance traveled was 1,481 miles.

We also conducted 146 temperature-depth profiles to monitor changes in subsurface ocean temperatures. Subsurface temperatures were warm, but not as warm as previous years. Overall, depredation from killer and sperm whales was down slightly from previous years.

Scientists also contrasted the catch from slinky pots and standard survey hook-and-line gear to compare species compositions and size selectivities of the two gear types.

Research Brief

Gulf of Alaska Bottom Trawl Survey

In 2021, we collected data from 529 stations out of an initial target of 540 stations from May 17 to August 16. Given a delayed start due to COVID-19, we randomly identified sets of 10-stations that could be dropped if the survey vessels fell behind schedule. One 10-station group was dropped in season, making the revised target of 530 stations. We sampled 45 strata in 2021, which is less than usual. As in 2019, the survey occupied stations in all depth strata except the 700–1,000 m stratum. Notably, instead of beginning survey work simultaneously, our two survey vessels started 17 days apart. Due to COVID-19 mitigation measures, the survey vessels only did one crew change instead of the usual four crew changes.

Catch composition was similar to past years with Pacific ocean perch being the dominant species, followed by arrowtooth flounder. We estimated collected age structures from over 11,000 fish and lengths from close to 186,000 fish. Preliminary estimated Pacific cod biomass decreased slightly from 2019, but catches were well distributed across the survey area. Preliminary estimated pollock and sablefish biomasses were higher than in 2019.

Sea surface and bottom temperatures returned to near average from record highs observed in recent years.

Research Brief

Aerial Survey for Steller Sea Lions

We collaborated with NOAA's Office of Marine and Aviation Operations to conduct range-wide aerial surveys. This is part of an international collaboration with the Department of Fisheries and Ocean, Canada, to assess the Eastern Distinct Population Segment of Steller sea lions to update the Stock Assessment Report in 2022.

In the Gulf of Alaska, the survey was conducted from June 23 to July 12. We flew 65 hours and collected 33,792 digital images of Steller sea lions. The survey was to monitor both the eastern Distinct Population Segment of the population in southeast Alaska and the endangered western Distinct Population Segment in the Gulf of Alaska and Aleutian Islands.

Personnel from L to R: Casey O'Toole (NOAA AOC), Ben Hou (AFSC), Lt. Kyle Cosentino (NOAA AOC), Lt. Christopher Licitra (NOAA AOC), Katie Luxa (AFSC), and Burlyn Birkemeier (UW CICOES)

Surveys in the Gulf of Alaska are of particular importance given the recent warm water anomalies that are occurring in this area. The most recent surveys in 2017 and 2019 indicated unusual changes in sea lion abundance in the Gulf of Alaska. The 2021 survey was important to help us assess if these trends are continuing. Warming waters could be influencing pup production and survival of adults and juveniles.

We timed the survey in Southeast Alaska with surveys of Steller sea lions in British Columbia, Canada by the Department of Fisheries and Oceans, and surveys along the west coast of the United States. Specifically, we completed aerial and uncrewed aerial system (UAS) surveys of the California, southern Oregon, and Washington rookeries and haulouts.

Data collected through this aerial survey and complementary vessel surveys supports NOAA Fisheries regional offices management efforts. We are providing estimates of Eastern Distinct Population Segment Steller sea lion pups and non-pup at rookeries and haulouts in the lower 48. Resource managers are using this information to inform their Steller sea lion Post-Delisting Plan and 2022 stock assessment reports.

Research Brief

Steller Sea Lion Remote Camera Analysis

To estimate survival, reproductive rates, and movements of Steller sea lions, we analyzed indirect observations collected from remote camera installations in the western and central Aleutian Islands west of Adak, Alaska. We processed 295,463 remote camera images with machine learning techniques and found 71 marked Steller sea lions.

Northern Fur Seal Population Assessment

We counted adult male fur seals in early July, we counted on the Pribilof Islands of St. Paul and St. George.

In August, a sample of pups were temporarily marked and counted to provide an estimate of pup production. We also conducted test flights with a UAS to determine their effectiveness for assessing population size. We conducted 24 hours of UAS flight time surveying northern fur seal rookeries and collected approximately 20,000 photos.

From August to November, we observed previously tagged northern fur seals to collect information for demographic studies of survival and reproduction on both islands. In late fall (Sept.-Oct.), we tagged pups and adult females.

This year we collected 238 northern fur seal diet samples from the field and processed 329 diet samples in the lab.

Eastern Gulf of Alaska Southeast Coastal Monitoring Survey

Our staff support this Alaska Department of Fish and Game survey using surface trawls, conductivity/temperature/depth (CTDs) profilers and other equipment to estimate phytoplankton (tiny plants) and zooplankton abundance. CTDs are a commonly used tool in oceanography to measure temperature and salinity at depth which are used by oceanographers to better understand ocean processes (e.g., photosynthesis, phytoplankton and concentrations of elements in seawater).

Information on juvenile salmon, young of the year gadids (e.g., Pacific cod, saffron cod, pollock), and sablefish are collected to better understand the implications of a warmer and more variable climate on their populations. This survey supports the Alaska Department of Fish and Game in producing a stock assessment for southeast Alaska pink salmon. Scientists are also collecting samples to monitor for harmful algal blooms (HABs).. This survey also supports the Alaska Department of Fish and Game in producing a stock assessment for southeast Alaska pink salmon. Information on juvenile salmon, young of the year gadids (e.g., Pacific cod, saffron cod, pollock), and sablefish are collected to better understand the implications of a warmer and more variable climate on their populations.

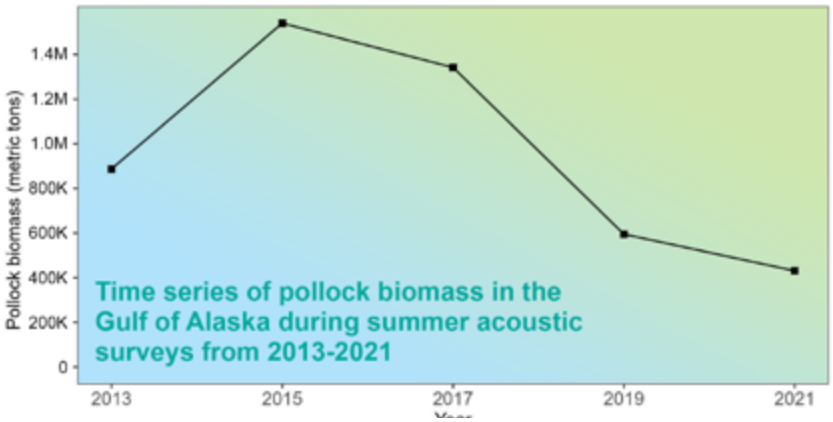
We observed below average ocean temperatures in Icy Strait and above-average densities of zooplankton during 2021. Salmon caught included pink, chum, sockeye and coho. Most were average- sized salmon indicating average feeding conditions prior to the survey. Juvenile pink, chum, and sockeye salmon feed on zooplankton and early marine growth of salmon is positively related to survival. This survey occurs in May, June, July.

Research Brief

Gulf of Alaska Summer Acoustic-Trawl Survey

Since 2013, we have conducted the summer acoustic-trawl survey primarily for Alaska pollock from early-June to mid-August. COVID-19 impacted our survey operations in 2021, and a reduced survey was conducted from June 4 to July 9. The survey area extended from the Islands of Four Mountains to Yakutat Trough at a reduced transect resolution. The area covered in the 2021 survey contained 98 percent of the 2019 survey pollock biomass. About 60 percent of the pollock biomass was on the shelf during this survey, with the majority of the remaining biomass observed within Shelikof Strait.

Matthew Phillips (A.I.S., Inc.) displays the first pollock caught during Leg 2 of the GOA summer acoustic-trawl survey aboard the NOAA Ship Oscar Dyson.



The total survey biomass for age-1+ pollock in 2021 was approximately 431,053 metric t compared to approximately 593,571 t in 2019. The biomass and numbers of age-2+ pollock were down in 2021 relative to 2019. In 2021, age-4 pollock (2017 year-class) comprised the bulk of the biomass, and age-1 pollock (2020 year-class) comprised the bulk of the numbers. Twenty-eight percent of the total pollock biomass was attributed to age-4 fish, and 84 percent of the total pollock numbers in the entire GOA survey were attributed to age-1 fish. In general, the weight for pollock at different lengths was similar to historic Gulf of Alaska summer data. However, an examination of age-1 pollock showed that mean length and weight were lower than previous surveys. This explains why the biomass of age-1 pollock was down although the numbers were up in 2021. It is possible that differences in the 2021 survey timing and water temperatures could be among the reasons for the differences in length and weight of age-1 pollock. Pollock abundance in the Gulf of Alaska summer acoustic-trawl survey indicated a similar relative abundance to results of the winter 2021 Shelikof Strait pre-spawning survey, the summer 2021 Alaska Department of Fish and Game survey, and the summer 2021 Alaska Fisheries Science Center Gulf of Alaska bottom trawl survey.

Estimates of Pacific ocean perch biomass were almost double their 2019 biomass estimates, approximately 277,941 t. We found these fish in large numbers in the Snakehead Bank area and east of Kodiak. They ranged in

size from 16 to 47cm. Estimates of Pacific capelin biomass were to 8,593 t, down 41%, from their 2019 biomass estimates. They ranged in size from 7 to 15cm. Pacific capelin were found in dense concentrations along Portlock Bank, as well as in the Shelikof Strait in the vicinity of the Semidi Islands.

A summary of the 2021 survey relative to 2019 showed:

- Age-1 pollock numbers were up 25 percent.
- Pollock age-1+ biomass was down 26 percent.
- Pacific ocean perch biomass was up 93 percent.
- Pacific capelin biomass, an important food source for many fish and marine mammals, was down 41 percent.

This survey was led by our Midwater Assessment and Conservation Engineering Program.

Western Gulf of Alaska Summer Beach Seine

We conducted this survey using beach seine nets, CTDs (connectivity, temperature and depth), and baited cameras off Kodiak, Alaska, in July and August (4 surveys, 16 sites across 2 bays) 2006-2021.

In 2018, we expanded the survey effort to the western Gulf of Alaska during July/August (75 sites across 14 bays). Our goal is to collect abundance and size, genetics, and diet data for young-of-the-year fish such as Pacific cod, saffron cod, and pollock. We also collect water temperature and salinity data, and monitor oxygen levels.

In 2021, scientists from our Newport and Kodiak Laboratories conducted 132 beach seines and 137 camera sets in the Gulf of Alaska to monitor juvenile Pacific cod pre-recruits (fish just prior to their reaching a size that they can be caught in commercial fisheries). Using data from two Kodiak bays (2006-2021) and 13 western Gulf of Alaska bays (2018-2021) in 2021, we found that the abundance of age-0 (in their first year of life) Pacific cod was approximately equal to long-term log mean. However, for fish that were born in 2020 (age-1 fish), we saw evidence of a large number of young fish. If these fish survive to become 3-year-olds, they will be available to support commercial, recreational, and subsistence fisheries in a few years. For age-0 pollock, based on baited camera results, the combined data from two Kodiak bays (2006-2021) and four Alaska Peninsula bays (2018-2021) showed relatively high abundance across age groups. However, the abundance for age-0 was spatially variable.

To learn about overall fitness and their ability to survive Arctic winters, we collected

- More than 1,500 fish and crab samples to assess fat levels.
- More than 2,200 fish and crab samples for fatty acid food-web biomarkers.

Pacific Marine Assessment Program for Protected Species Survey

We completed the Pacific Marine Assessment Program for Protected Species (PacMAPPS) survey in the northern Gulf of Alaska in August. PacMAPPS is a partnership among federal agencies to conduct surveys to assess the abundance of multiple whale, dolphin, and porpoise species.

A total of 2,330 km of on-effort tracklines was surveyed, with an additional 372 km surveyed during transit and sub-optimal conditions. We had 667 sightings of marine mammals (including duplicates and resights). Primary species sighted include North Pacific right, fin, humpback, killer, and sperm whales, and Dall's and harbor porpoise. We successfully deployed 96 sonobuoys, which recorded 133.7 hrs of sound. Acoustic detections were in good agreement with the visual sighting data; sonobuoys also recorded seismic airguns and vessel noise. We also retrieved a long-term bottom-mounted passive acoustic recorder mooring (records sound year-round) in Barnabas Trough and deployed a new one. Finally, a total of 20 CTD casts were conducted, with 119 nutrient samples collected.

Research Brief

Aerial Surveys of Harbor Seals

In August and September, we completed aerial photographic surveys of harbor seals on land and in glacial ice habitats in Southeast Alaska. We used standard oblique photography and a multi-spectral 9-camera vertical array aboard a NOAA Twin Otter.

During these surveys, we flew 3,500 km (~2200 mi) and collected 60K images (IR and UV). Roughly 110 person-days (3pp x 30 days; 1pp x 20 days) were spent during this effort. These surveys extend a decades-long time series of seal abundance allowing for the continued tracking of population health, and, as harbor seals are a keystone predator, the health of the coastal ecosystem.

Bering Sea Surveys

2021 EcoFOCI Spring/Fall Mooring Cruise and Hydrographic Survey

In May, scientists from the Alaska Fisheries Science Center's RACE Division and Marine Mammal Laboratory, NOAA Research's Pacific Marine Environmental Laboratory, and the University of Alaska Fairbanks conducted this survey aboard the NOAA ship *Oscar Dyson*. The overall research objective was to determine how varying biological and physical factors influence the Bering Sea marine ecosystem. This survey has been ongoing since 2010. This year the fall survey was canceled to accommodate NOAA research vessel repair. As a result, we didn't have data to assess zooplankton abundance during a critical time of year, when marine life builds energy reserves for winter. Zooplankton are key prey for fish and other species. Biological and oceanographic information helps us better understand fish condition and overwinter survival.

The objectives of this spring/fall surveys are to

1. **Service** oceanographic and passive acoustic moorings that measure water column and sea ice properties and detect marine mammals and sounds from human activities.
2. **Sample** the water column for zooplankton, larval fish, and bottom-dwelling organisms.
3. **Deploy** drifters to measure currents.
4. **Deploy** sonobuoys to monitor marine mammal sounds to detect their presence in real time.

Key Findings

The survey found a well mixed water column in the south with evidence of some stratification of the mixed layer north of the Pribilof Islands. This appeared to be driven primarily by melting ice, low salinity water at the surface, and small differences in temperature between bottom and surface. Only two stations north of the Pribilof Islands showed evidence of phytoplankton bloom conditions, thus the majority of the survey was conducted prior to the spring bloom. The spring bloom began to occur to the south during the latter half of the survey coincident with sufficient heating of the surface layer leading to partial stratification. Overall, the zooplankton community appeared similar to that of a year with average ice conditions. Abundant nauplii suggesed good conditions for larval fish and the potential for increasing abundances of the important copepod *Calanus* later in the year when they are the primary prey for larval walleye pollock. Abundant euphausiids were present, suggesting good overwinter survival and an available prey base for overwintering fish from prior year class.

Across this and other EcoFOCI program supported surveys in 2021, scientists took 694,569 pictures of zooplankton (planktonic marine animals).

These data contribute to an ongoing multidecadal research program. This program is dedicated to understanding and predicting the dynamic relationships among climate, fisheries, and the marine environment to ensure sustainability of Alaska's living marine resources and healthy ecosystems. We are providing rapid zooplankton assessment (timely information) to inform annual ecosystem status reports, which are used by fishery resource managers to provide context when assessing the condition of key commercial fish stocks.

Research Brief

Far Left: AFSC biologists Bianca Prohaska and Connor Cleary collecting tissue samples from Pacific cod. Left: AFSC fishery biologist Emily Markowitz extracting otoliths from a northern rock sole. Below: Inserting a satellite tag on a Pacific cod.

Eastern Bering Sea and Northern Bering Sea Bottom Trawl Survey for Groundfish, Crab and Other Bottom Dwelling Species

Scientists conducted the survey from two commercial fishing vessels in the eastern Bering Sea and the northern Bering Sea from May 31 to August 22. In 2021, the cold pool (< 2) had a reduced extent in the eastern Bering Sea shelf area. The cold pool was only present north of St. Matthew Island.

Scientists collected the total lengths for 48,178 individual fish representing 21 species. They measured 19,518 crabs (three species) to better understand growth and maturity. They collected 2,413 otoliths (ear stones) from eight species of fish and stomachs from four species of fish to better understand fish age and diet.

Groundfish Results

- About 19 percent more Pacific cod in the eastern Bering Sea in 2021 as compared to 2019 and about 38 percent less Pacific cod in the northern Bering Sea during this time frame.
- Walleye pollock biomass was down 59 percent in the northern Bering Sea and down 44 percent in the eastern Bering Sea.
- About an 88 percent decline in saffron cod in the northern Bering Sea and very few saffron cod in the eastern Bering sea.
- Arctic cod abundance was very low throughout the entire survey area.
- A slight increase in halibut abundance across the survey area.
- Approximately a 23 percent decline in northern rock sole biomass in the northern Bering Sea and a slight increase in biomass in the eastern Bering Sea survey area.
- Yellowfin sole abundance was down in both areas of the survey.
- Overall across both areas, fewer plain sculpin and shorthorn sculpin compared to 2019.
- Approximately a 35 percent increase in purple orange sea star in the northern Bering Sea and lower abundance in the eastern Bering Sea, and continued declines in sea peach in both areas.
- The situation for forage fish was a mixed bag.
  - Herring declined across the survey area.
  - Pacific capelin abundance declined in the eastern Bering Sea and was slightly up in the northern Bering Sea.
  - Rainbow smelt abundance was down significantly in the northern Bering Sea but up in the eastern Bering Sea. However, the survey typically doesn't catch large amounts of capelin or rainbow smelt.

Scientists also conducted several special projects during this year's survey, including sampling for shellfish for evidence of harmful algal blooms, assessments of fish condition (fat content),and tagging of Pacific cod.

Crab Results

Scientists collected crab samples for eight special projects during this survey. Mature male biomass of all crab stocks managed under a federal fishery management plan declined to the lowest in the 1975-2021 time series.

SNOW CRAB

- In the 2021 survey, snow crab legal male abundance declined by 69 percent from the 2019 estimate.
- Mature female abundance declined 70 percent from the 2018 estimate.
- Immature male and female abundances were down 96 percent and >99 percent, respectively, from the 2018 estimates.
- Scientists saw a larger proportion of old shell males and females.
- Fishery-preferred sized males and mature males shifted northwest, but mature females showed little changes in distribution. Immature male and female abundances shifted north.
- The high incidence of old shell (older) crab gives an indication of snow crab population change.
- In the northern Bering Sea, snow crab abundance was down 54 percent as compared to the last time the survey was conducted in 2019.
- Scientists also saw a higher prevalence of bitter crab syndrome in snow crab than in recent surveys
- There was also more overlap with Pacific cod and other groundfish.
- Scientists do not believe the snow crab biomass just shifted distribution onto the slope. The slope survey, which has not been conducted since 2016, covers <10 percent of eastern Bering Sea shelf area and accounted for < 0.1 percent of the 2018 eastern Bering Sea snow crab biomass. However, differences in survey gear make direct comparisons of biomass estimates from the shelf and slope surveys difficult.

RED KING CRAB

In 2021, the cold pool did not extend to the Bristol Bay area to influence the distribution of red king crab. Our June sampling indicated a significant proportion of females had not completed the molt-mate cycle. As a result, the female areas were re-sampled in August to estimate available female abundance and determine reproductive status.

- In the southeastern Bering Sea, mature female abundance declined 25 percent and mature male abundance increased 26 percent compared to 2019.

AFSC crab biologist Erin Fedewa examines red king crab specimens in the eastern Bering Sea.

- Declining trends in immature male and female abundances occurred in recent years.
- Survey results indicated a northern shift of the center of distributions of mature male and female abundances.
- Red king crab abundance was up 26 percent in 2021 as compared to 2019 in the northern Bering Sea.

TANNER CRAB

- Tanner crab mature male abundance decreased over 20 percent in 2021 compared to 2019 in areas both east and west of 166°W.
- However, pre-recruit male (animals not large enough to be caught and retained in commercial fisheries) and mature female abundances increased significantly in both areas in 2021, compared to 2019.
- Legal male abundance declined ~30 percent in both regions from 2019 to 2021.
- High abundances of small size (pre-recruit) crabs were seen during the 2018-2019 and 2021 surveys but progression to exploitable sizes over the years was not detected.

OTHER FEDERALLY-MANAGED CRAB STOCKS

- There was a 42 percent decline from 2019 in legal male abundance of St. Matthew blue king crab.
- The legal male biomass of both Pribilof Island red king crab and Pribilof Island blue king crab were below the 20-year mean.
- Blue king crab abundance in the northern Bering Sea was down 12 percent as compared to 2019 and overall in the eastern Bering Sea down ~30 percent.

Eastern Bering Sea Salmon Bycatch Reduction Research Survey

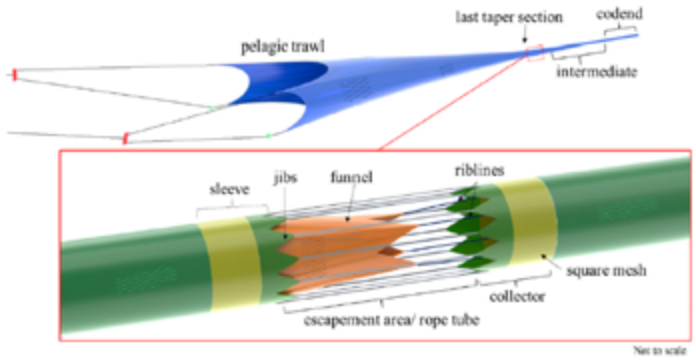
In the summer of 2021, the Conservation Engineering group (CE) within the Midwater Assessment and Conservation Engineering Program collected data in the Eastern Bering Sea, aboard a trawl catcher vessel, to conclude a five year research study evaluating bycatch reduction devices (BRDs) used in the walleye pollock fishery. Twenty-six research tows were completed using standard commercial fishing operations, catching 772 mt of pollock, and collecting 515 hours of video footage and 500 salmon lengths.

Incidental capture of Pacific salmon (prohibited species) has the potential to close the pollock fishery in Alaska. Reducing salmon bycatch prevents closures and supports directed harvest of salmon in other fisheries. BRDs allow salmon to escape from the trawl once inside (salmon "excluders"). Despite two decades of research, much is unknown about how these excluders work mechanistically, how salmon behave in and around the devices, how to optimally design the excluders, and how to most effectively evaluate the efficacy of the excluders.

In 2017, CE began a research study to address these knowledge gaps. In 2017 and 2018, we evaluated salmon behavior in response to artificial light both in the trawl and in a laboratory setting. In 2018 we also worked on a collaborative project to evaluate salmon vision to understand their visual spectrum while in marine residence. In 2019, we collaboratively developed a new salmon excluder design, focusing on manipulating water flow and providing maximum escapement opportunities.

Testing of this excluder design informed how salmon engage with these devices. We learned that, despite nearly 360° unimpeded access to escapement, there were salmon that did not escape. For excluders to work, the animal must be motivated to escape, be able to perceive the escapement opportunity, and have access to it. This work indicated that providing access to a large escapement area alone is insufficient for full escapement, and highlighted the role of motivation and salmon's ability to perceive an escapement opportunity despite fast tow speeds.

The research conducted in 2021 focused on using cameras to evaluate: (1) if blue artificial light increases perceptibility of the escapement area; (2) how (actively or passively) and where in the excluder salmon are escaping; and (3) how to optimize methods for quantifying escapement of both salmon and pollock. In addition, based on 2019 data that showed increased escapement during turns and when hauling back the gear, we are also evaluating (4) what prompts salmon to move forward in the trawl. Following analysis of the data collected from 2017-2021, we will have a more comprehensive mechanistic understanding of how these devices perform and what influences their efficacy. This information will allow us to provide recommendations to the fleet and gear designers. The methods we develop will also be shared to assist those who conduct similar research on BRDs. Finally, the data collected during the field research is being used to develop machine learning (artificial intelligence) approaches for detecting salmon in the trawl.



Above: Research partners' conceptual model of a new salmon excluder. Below: Recording video cameras attached inside the CE developed salmon excluder to capture footage of salmon and pollock inside the bycatch reduction device, both with and without the inclusion of blue artificial lights (bottom image).

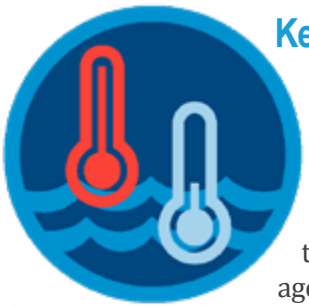
Northern Bering Sea Surface Trawl and Ecosystem Survey

In 2021, we conducted the northern Bering Sea surface trawl and ecosystem survey August 27–September 19. This is a multi-disciplinary research survey involving the Alaska Fisheries Science Center, the Alaska Department of Fish and Game, the U.S. Fish and Wildlife Service, the Pacific Marine Environmental Laboratory, and University of Alaska.

The survey objectives were to collect information on

1. **Physical,** biological and oceanographic conditions.
2. **Phytoplankton** community composition and the presence of HAB species and toxins;
3. **Distribution,** abundance, and size of salmon and other pelagic fish species with surface trawl operations.
4. **Diet,** condition, and trophic ecology of fish.
5. **Environmental** DNA and genetic origin of salmon.
6. **Ecology** of juvenile snow crab and yellowfin sole with benthic grab and beam trawl operations.
7. **Distribution** and abundance of seabirds.
8. **Salmon** shark migration.

The Arctic-Yukon-Kuskokwim (AYK) Region has experienced unprecedented run failures for Chinook, chum, and coho salmon. All salmon directed fisheries within the Yukon River were closed during 2021. Resource managers at the state use data and specimens collected during this survey to gain insight into the marine ecology and survival of Yukon River salmon stocks. Collected data also helps guide pre-season assessment and management strategies for Yukon River salmon.



Key Findings

Water Temperatures

In 2021, water temperatures cooled from the record warm temperatures in 2019. However, surface temperatures remained slightly above average during the 2021 survey. The coolest surface temperatures were just north of St. Lawrence Island and the coolest bottom temperatures were south of St. Lawrence Island.

Temperatures on the bottom have a much greater range than surface temperatures in the Northern Bering Sea. The surface temperatures ranged from 7 to11 degrees Celsius, whereas the bottom temperatures ranged from subzero temperatures to 11 degrees. The temperature data collected during this survey is very consistent with the temperature data from the bottom trawl survey. However, the bottom trawl surveys sample a much larger portion of the northern Bering Sea and therefore provide a more complete picture of the water mass types and temperature variation within the Northern Bering Sea.

Zooplankton

Small copepod species are a diverse group of zooplankton (planktonic animals) that are less than 2 mm in length. They are the most abundant species of zooplankton with numbers that are typically in the range of 1,000 - 10,000 individuals per square meter. They occur throughout the northern Bering Sea and their abundance has been relatively stable over time. In 2021, abundance was consistent with previous years. Large copepod species are less abundant, but they are an important energy-rich food source. Their abundance has been variable over time, and their abundance in 2021 was a bit higher than recent low sea ice years. They reached their highest densities in the Bering Strait region.

The fat or lipid content of zooplankton is a key part of their nutritional value. The fat content of copepods in 2021 were typically in the range of 10-15 percent of their body weight and their highest values were offshore and in the southern portion of the survey.

Euphausiids are another important species group of zooplankton. They are often referred to as krill. Their lipid levels were lower than copepods, in the range of 2-5 percent of their body weight. Their fat content was similar across the survey, with slightly higher values in stations just northeast of St. Lawrence Island.

Larval Fish and Crab

We use a beam trawl to help us count fish and small crab in the middle of the water column. The small stages of crab that are sampled in the beam trawl gear are rarely captured in the bottom trawl survey gear. Therefore, these data complement the crab assessment data that are collected during our bottom trawl surveys. Juvenile Chionoecetes crab (snow crab and Tanner crab, which are indistinguishable at this stage of development) were present at intermediate depths and in both the southern and northern regions of the survey.

Juvenile yellowfin sole were the most abundant species of fish captured in the beam trawl samples. They occurred in the nearshore stations.

Shrimp were the most abundant species in the beam trawl samples. Ridged crangon and northern shrimp (also known as pink shrimp) were two common species captured in the beam trawl gear. Both species of shrimp were present throughout the survey area. However, their highest densities were in Norton Sound.

Scientists also use a surface trawl to catch a variety of species. Juvenile Chinook salmon have been an important part of the survey. Our research has focused on Yukon River Chinook salmon as they account for over 80 percent of the juveniles in the northern Bering Sea. We know that Yukon River Chinook salmon are important to subsistence fisheries within Alaska and the Yukon Territory. They are also important to international Yukon River treaty negotiations between the U.S. and Canada. Juvenile Chinook salmon were distributed in the nearshore stations of the survey. This distribution was atypical for Chinook salmon. They are usually broadly distributed across the survey area.

Juvenile Chinook abundance was below average in 2021. Abundance has been below average since 2017. We use genetic stock identification to estimate the abundance and forecast returns of individual stocks of Chinook salmon.

The largest group of salmon in the Yukon River are Canadian-origin Chinook salmon. The preliminary analysis suggests that abundance estimates may be below average in 2021. Historically juvenile abundance has provided a reasonably good indicator of future Yukon River adult returns.

Juvenile chum salmon were only found in nearshore stations. This was atypical for chum salmon as they tend to be even more broadly distributed than Chinook salmon in the northern Bering Sea.

Pink salmon were also in the nearshore stations and their abundance was particularly low in 2021. This abundance index is significantly related to adult returns to the Yukon River and Norton Sound. As a result, we expect to see low numbers of pink salmon returning to the northern Bering Sea in 2022.

The abundance index for coho salmon is very much a work in progress. We hope to genetically separate Norton Sound and Yukon River stocks of coho salmon. This may provide a clearer picture of their status in the northern Bering Sea. The catch of coho was high in 2021. In fact, the coho biomass index was close to the highest levels we have ever seen in the northern Bering Sea.

Saffron cod are usually present in the shallow nearshore stations of the survey. However, the catch of saffron cod was quite low in 2021. We only saw a few saffron cod near Norton Sound and the Bering Strait.

Unlike saffron cod, young-of-the-year or age-0 pollock and Pacific cod occur in the offshore stations of the survey. We use information from the survey to study their growth, diet, and condition in the northern Bering Sea. There was a fairly large increase in the number of age-0 Pacific cod in the survey in 2021 with a total catch of just over 250. Although that is not many fish compared to previous years, we typically catch only a few age-0 Pacific cod during the survey (< 20).

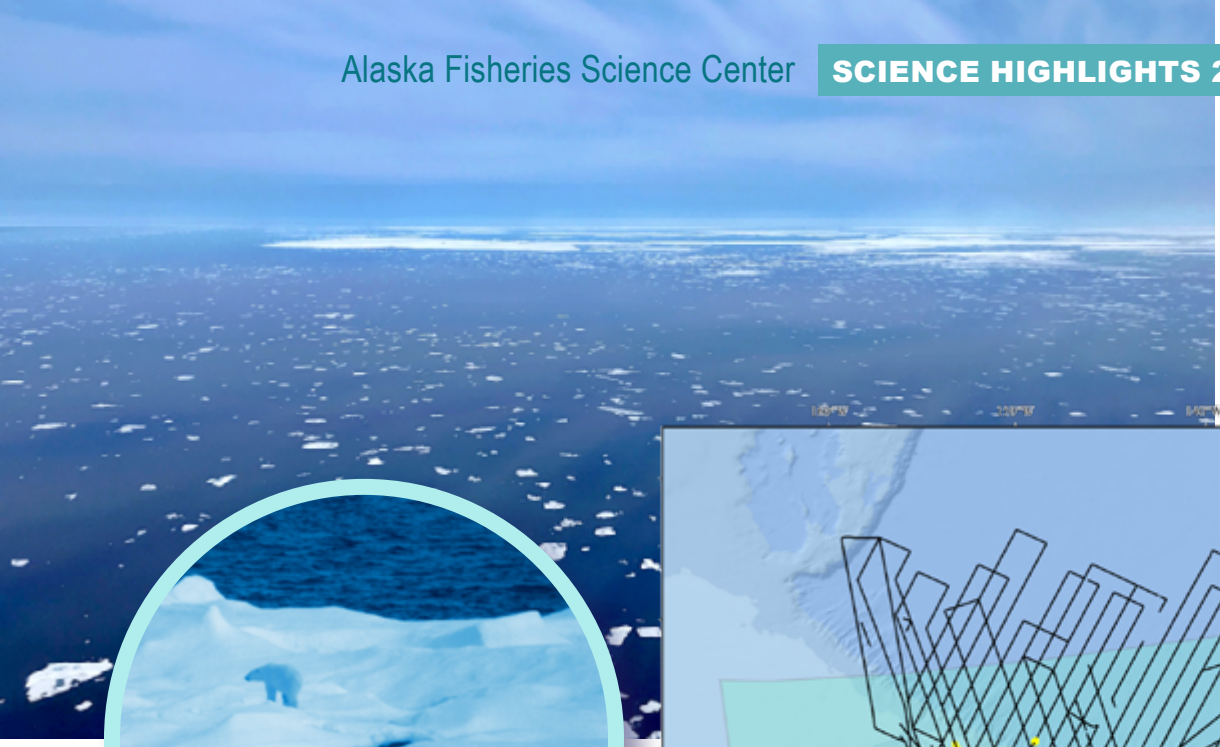
Herring are the largest biomass of fish that are captured in the surface trawl gear. Herring were present throughout the survey area with young-of-the-year herring in the nearshore stations and older ages distributed further offshore. The catch of herring was quite low in 2021.

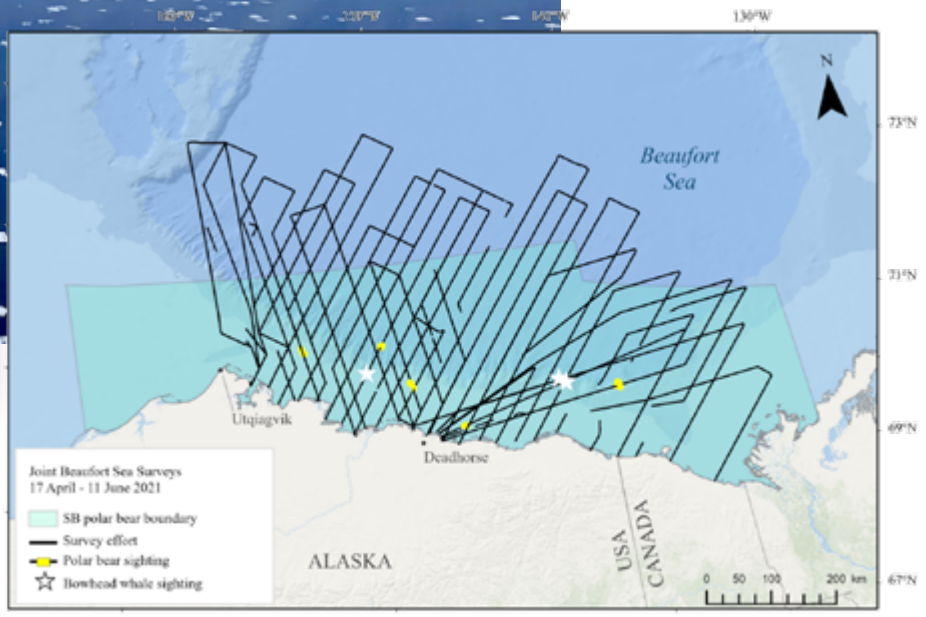
Capelin were present in the Bering Strait region. Our catch of capelin tends to be temperature dependent and their abundance is higher in cooler years. The abundance of capelin has been particularly low in recent low ice years. It was good to see a few capelin in 2021 as they are an important forage fish.

By combining the biomass of all small fish species, such as herring, capelin, juvenile salmon, and age-0 pollock, a forage fish index was established for the Northern Bering Sea. FY21 marked a record low index for the northern Bering Sea.

Two sharks were tagged. Marine bird surveys were also completed in 2021. This work was led by the U.S. Fish and Wildlife Service (USFWS). USFWS has monitored marine birds on this survey for 8 years and has been able to establish a good baseline for marine birds in this region of the northern Bering Sea.

Research Brief





Chukchi and Beaufort Surveys

Aerial Surveys of Ice-Associated Seals and Polar Bears

From April to June we collaborated with the U.S. Fish and Wildlife Service to complete the Joint Beaufort Sea Surveys (JoBSS) for ringed seals, bearded seals, and polar bears. This included

- Conducting 28 survey flights, covering 18,618 km.
- Conducting 166 disturbance trials to assess whether survey activities are affecting wildlife behavior.
- Collecting over 900,000 sets of multispectral imagery (2.7M color, IR and UV images).
- Spending 170 person days in the field, plus 242 days of shelter-in-place and home isolation in response to COVID-19.
- Processing the 2.7M images collected in a week; it took 170 hrs to manually review detections.

This effort demonstrated the use of edge computing with the application of AI models applied in real time to multispectral imagery to detect and classify target species for the first time.

We also conducted initial tests of a small uncrewed aircraft system (sUAS) at the Long Marine Laboratory, University of Santa Cruz. The goal was to collect information about the body condition of ice-associated seals. Body condition is a key indicator of population health and productivity. However, it is expensive and challenging to collect using traditional methods that require catching and measuring a large sample of seals. If feasible, using a sUAS will allow for more body condition measurements to be collected in less time, and with less disturbance. We spent 25 person-days (5 people for 5-days) conducting this UAS testing.

Research Brief

Washington, Oregon and California Surveys

Several of the species we study have ranges that extend outside of Alaska. This includes Steller sea lions, northern fur seals, and gray whales. We conduct studies in Washington, Oregon, and California to inform our understanding of these species. In some of these habitats California sea lions also occur. We collect and provide information to NOAA Fisheries West Coast Regional Office to support management measures for California sea lions.

Key FY21 Accomplishments include:

- Collaborated with our Canadian colleagues to monitor the movements of a Pacific Coast Feeding Group gray whale satellite-tagged with a newly designed implantable tag in September 2020; the tag transmitted for 364 days, one of the longest records for a gray whale.
- Completed the 2018-2019 abundance estimates for Pacific Coast Feeding Group gray whales; the data are needed by NOAA Fisheries West Coast Region to evaluate the possible impacts of a gray whale harvest by the Makah Tribe under a Marine Mammal Protection Act waiver request.
- Completed aerial and UAS surveys of the California, southern Oregon, and Washington rookeries and haulouts of Eastern Distinct Population Segment Steller sea lions as part of an international collaboration to complete a range-wide survey. We provided Steller sea lion pups and non-pup at rookeries and haulouts in the lower 48 in support of the Steller sea lion Post-Delisting Plan and 2022 Stock Assessment Reports.
- Completed California sea lion and California stock northern fur seal stock assessments using fixed wing aerial surveys and high-resolution digital photography.
- Marked or tagged 440 seal and sea lions.

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